ARMY RESEARCH LABORATORY

The Effects of an Auditory Versus a Visual Presentation of Information on Soldier Performance

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Abstract

This report describes a field study designed to measure the effects of an auditory versus a visual presentation of position information on soldier performance of land navigation and target acquisition tasks. Measures of situational awareness, stress, cognitive performance, and workload were also obtained. In the auditory mode, position information was presented in verbal messages. In the visual mode, the same information was provided in text and graphic form on a map of the area of operation presented on a helmet-mounted display (HMD). During the study, 12 military volunteers navigated densely wooded unmarked paths that were 3 km long. Although no differences were found between the two display modes in the frequency at which navigational and other tactical information was accessed, the analysis of responses to probe questions indicated that participants maintained a greater awareness of position with respect to waypoints, targets, and other units when information was presented visually than when information was presented auditorily in verbal messages. In the auditory mode, as the participants' perceptions of time demands increased, post-test scores on a logical reasoning task tended to be higher than pre-test scores. Although visual presentation of information appeared to enhance position awareness, differences between the two display modes in navigation and target acquisition performance were not found to be statistically significant. The findings of the investigation suggest differences in cognitive processing requirements between the two displays and the impact of attentional focus and practice on cognitive performance.

ACKNOWLEDGMENTS

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Special thanks to the Marine Corps System Command at Quantico, Virginia, particularly Joe Miller, Darrell Harris, and Dave Cherrix for coordinating the superb support of the Marines in this investigation, and to the Marine Corps Company Commander who most admirably demonstrated dedication to his men and service.

We are most grateful to the Marines and Army soldiers who participated in this field study. We thank them for their enthusiasm, dedication, and opinions, and particularly their patience and sense of humor.

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EXECUTIVE SUMMARY

This report presents the results of the second in a series of field investigations designed to quantify the effects of helmet-mounted display (HMD) technology on the performance of the dismounted infantry soldier. The objective of this experiment was to measure soldier performance of land navigation and target acquisition tasks when position information was presented visually on an HMD and to compare these data with performance when the same information was presented auditorily in verbal messages. Measures of situational awareness, workload, stress, and cognitive performance were also obtained.

In this study, each of 12 military volunteers performed land navigation and other soldier tasks in each of the two display conditions (i.e., auditory and visual). In each condition, the participant was provided information about his position with respect to waypoints, the "optimum" straight-line path to these waypoints, targets, and other friendly and enemy units. In the visual condition, position information was overlaid on a map of the area of operation that the participant viewed on an HMD. In the auditory condition, the same information was presented through speakers installed in the participant's helmet. In both conditions, the participant accessed each type of information via a keypad that he wore on his belt.

In both conditions, the participants wore a backpack that contained the digitally aided soldier for human engineering research (DASHER) system. DASHER, which was developed by Sytronics, Inc., Dayton, Ohio, consists of a small commercial computer, a global positioning system (GPS) receiver, and an electronic compass. The system is a self-contained simulator-recorder that uses a position-based script to simulate connectivity with a command network that presents information about troop movements as well as data for land navigation. In this study, DASHER generated both the visual and auditory displays and recorded the participant's performance.

Each participant was trained and tested in one equipment condition before being trained and tested in the other. Training included both classroom and field instruction in which the participant was trained to a point at which he achieved an asymptote in the performance of land navigation and other soldier tasks using information presented in each of the two display modalities.

Measures of stress and cognitive performance were obtained on a day before training and testing, as well as before and immediately after training and testing in each display condition.

During testing, participants navigated an unmarked path through wooded terrain, traveling in opposite directions for each condition. The path was 3 kilometers long and consisted of four legs of different lengths. The participant was instructed to navigate each leg of the path as quickly and as accurately as possible, deviating from a straight-line course only as needed to avoid obstacles. The participant's position was recorded at a rate of 1 Hz. Measures of navigational performance included distance traveled and velocity. While navigating, the participant was required to monitor the location of targets that had been placed along the path and to acknowledge when a target was 50 meters from his position by depressing a designated button on his keypad. The participant was then required to find and destroy the target as quickly as possible. Measures of target acquisition performance included the number of targets detected and destroyed and the time to destroy these targets. At predetermined coordinates along each path, the participant also received probe questions that assessed his awareness of his position with respect to waypoints, targets, and other units. In each display condition, the frequency at which the participant accessed navigational, target, and unit information was recorded.

At the conclusion of testing in each condition, the soldier rated his workload experience using the National Aeronautics and Space Administration-Task Load Index (NASA-TLX). Questionnaires were also administered to obtain information about display use, problems the participant may have experienced, and display preferences.

The data analyses indicated that differences between display conditions in navigation and target acquisition performance were not statistically significant. However, significant main effects were found for path leg in the analysis of travel velocity ($p < .05$), the number of targets destroyed ($p < .001$), and the time to destroy these targets ($p < .05$). These main effects for path leg are primarily attributed to differences among legs in the density of vegetation and the effects these differences had on movement and the ability to see targets at distances.

Differences between display conditions in the frequency at which each type of information was accessed were not statistically significant; however, the analysis of responses to probe questions indicated that participants maintained a greater awareness of their position with respect to waypoints, targets, and other units when this information was presented visually than when the same information was presented auditorily in verbal messages ($p < .001$).

The results of the analysis of psychological stress perception measures indicated an increase in levels of hostility ($p < .05$) and dysphoria ($p < .05$) between pre- and post-test sessions in both display conditions. Differences between display conditions, however, were not statistically significant. Levels of salivary amylase showed low to no stress for condition or session.

No differences were found between display conditions in the participants' ratings of workload; however, significant relationships were found between sources of workload in both conditions. Correlations were also found between workload ratings and performance of navigation and target acquisition tasks. In the auditory mode, as the participants' experiences of physical workload increased, time to destroy targets also tended to increase ($p < .01$). In the visual mode, as perceptions of time demands increased, time to destroy targets tended to decrease ($p < .05$).

No differences were found between conditions in cognitive performance. In the visual condition, however, post-test scores on the spatial rotation task were higher than pre-test scores ($p < .01$). This finding is attributed to practice the soldiers received in mentally rotating the visual map display that was fixed in the "north-up" direction. In addition, significant correlations were found in both display conditions between sources of workload and performance of some cognitive tasks. In both display conditions, a relationship was found between the participants' perceptions of time demands and their performance of the logical reasoning task. The findings indicate that, in the auditory mode, as time demands increased, post-test scores on the logical reasoning task tended to be higher than pre-test scores ($p < .01$), whereas in the visual mode, as time demands increased, post-test scores on the logical reasoning task tended to be lower than pre-test scores ($p < .01$).

The participants were split in their opinion as to the display modality in which target and unit information should be presented, but most preferred that navigational information be displayed visually. Some participants believed that "it took more time" to navigate in the visual mode because of the need to stop to view the HMD, but the visual information, they added, was "easier to follow" and "easier to recall." The auditory condition, one commented, required "more memorization."

The findings of this study appear to indicate that soldiers can maintain a greater awareness of their location with respect to waypoints, targets, and other units when position information is presented visually on an HMD than when this information is presented auditorily in verbal messages. Differences between display conditions in position awareness are attributed to a combination of factors that may have affected the participants' ability to retain and accurately recall information. In the visual mode, graphical representation of position information may have facilitated "chunking." In the auditory mode, position information was presented in series rather than in parallel, and transformation of these data into a mental image of position may have been more difficult.

THE EFFECTS OF AN AUDITORY VERSUS A VISUAL PRESENTATION OF INFORMATION ON SOLDIER PERFORMANCE

INTRODUCTION

Advanced sensor and display technologies can increase the soldier's knowledge of the battlefield and can enhance decision-making ability, but the benefits that this additional information has to offer depend upon the soldier's ability to capture, process, and act upon this information—quickly and accurately. "Who gets what information when and how?" is a simplified expression of a multitude of critical questions that will impact individual soldier and higher unit performance. The "how" refers to the design of the display (e.g., head mounted or hand held), the mode of information presentation (e.g., visual and auditory), and the form in which this information is presented (e.g., graphics and alphanumerics, tones and speech).

It is expected that, in the future, much of the information about the battlefield will be presented to dismounted soldiers visually on a helmet-mounted display (HMD). Therefore, research has focused on the design of visual displays and the impact that HMDs might have on dismounted soldier performance. In a recent field experiment, soldiers navigated more efficiently and experienced lower levels of mental workload using information integrated on an HMD than they did when using standard land navigation equipment (Glumm et al., 1998). In this investigation, the soldiers claimed that they were not distracted any more by the HMD than they were by the standard navigational tools. The findings of the study appear to favor the HMD, but the authors caution that the results could be reversed with other display formats or increases in the amount of information presented. Information overload can potentially be as detrimental to soldier performance as a poorly designed or unreadable display.

Auditory displays may be useful in off-loading information from the potentially over-burdened visual channel (McKinley, Ericson, & D'Angelo, 1994; McKinley et al., 1995). Reaction time to auditory stimuli is shorter than that to visual cues (Riggs, 1971), and therefore, auditory signals can be particularly useful in alerting the soldier to critical information within the visual display. However, in addition to augmenting visually displayed information, auditory displays may also serve as the primary source of information for the performance of some soldier tasks. Although previous research has indicated benefits of auditory displays in waypoint navigation (McKinley & Ericson, 1995), most of these experiments have been conducted in the laboratory and focused on the performance of sedentary listeners.

In the present field experiment, it was hypothesized that navigation and other position information, such as the location of enemy and friendly units, could be successfully off loaded from the visual to the auditory channel without degrading soldier performance. For the purpose of this study, auditory information was presented in computerized verbal messages.

OBJECTIVE

The objective of this field experiment was to measure soldier performance of land navigation and target detection tasks when position information was presented visually on an HMD and to compare these data with performance when the same information was presented auditorily in verbal messages. Measures of situational awareness, workload, stress, and cognitive performance were also obtained.

METHOD

Test Participants

A total of 12 male military personnel participated in this investigation. Ten (10) of the 12 participants were Marines and two (2) were Army infantry soldiers. The military specialty of each of the Marines was 0311, which is an equivalent of the Army's military occupational specialty (MOS) 11B, dismounted infantry soldier. The MOSs of the two Army soldiers were mechanized infantry (11M) and combat engineer (12B). The participants ranged in age from 22 to 35 years, with an average age of 24.6. Their time in service ranged from approximately 3 to 17 years, with an average of 5.5. Time in MOS ranged from 9 months to 17 years, with an average of 5.1. When asked to rate their land navigation skills, five of the participants rated their skills as "excellent," six as "good," and one as "fair." All met visual acuity requirements of 20/20 in one eye and at least 20/30 in the other eye (corrected or uncorrected) and passed tests of color and stereo vision. All were administered an audiogram and possessed hearing within thresholds acceptable to the U.S. Army.

Apparatus

In both experimental conditions, the participants wore the standard battle dress uniform (BDU) or the Marine Corps equivalent and the personal armor system for ground troops (PASGT) helmet. All carried a dummy M16 rifle and an Army lightweight individual carrying equipment (ALICE) backpack (see Figure 1). The backpack contained a small computer, global positioning system (GPS) receiver, and an electronic compass. This equipment was integrated by Sytronics, Inc., of Dayton, Ohio, in a system called the digitally aided soldier for human engineering research (DASHER). DASHER, which includes a 3.6-kilogram (8-lb) 12-volt battery, weighed approximately 12.7 kilograms (28 lb). The system used a position-based script to simulate connectivity with a command network that presented information about troop movements as well as data for land navigation. In each of the two experimental conditions, DASHER generated the visual and auditory displays, initiated mission tasks, and recorded the participants' performance. In this system, the position coordinates of waypoints, targets, and other mission events or tasks were pre-programmed in the computer. During the mission, the participant's location and orientation, as measured by the GPS and the electronic compass, were updated once a second. A computer routine calculated the participant's distance and bearing with respect to the preprogrammed coordinates. Visual or auditory display of this updated position information was initiated, based upon participant input to a keypad. In the auditory mode, pre-recorded voice messages, stored digitally in computer files, were played. In the visual mode, text and graphical data were displayed on a map of the area of operations presented on the HMD. A task or mission event was automatically initiated via a prerecorded auditory message when the participant was within a 20-meter radius of the pre-planned coordinate.

Figure 1. Marines equipped for operations in the auditory (left) and visual (right) display conditions.

A description of the major items of equipment used during the study, as well as the components of the DASHER system, follows.

Helmet-Mounted Display and Computer (the Trekker™ system)

In the visual display condition, position information was overlaid on a map of the area of operation that the participant viewed on an HMD. The HMD is part of a system developed by Rockwell International called the Trekker™. Trekker™ consists of a headset and small computer which is part of the DASHER system (see Figure 2). The headset consists of an occluding, monocular display developed by Kopin, and a boom microphone. The display is a monochrome active matrix liquid crystal display (AMLCD) with 640 horizontal by 480 vertical lines of resolution. Focus and brightness controls are integrated into the headset. The display slides left or right along the top of the unit to accommodate the desired viewing eye. The monocle assembly rotates on its arm and can be manipulated vertically to provide adjustment for eye relief and display stowage. For this investigation, the HMD was secured to the participant's PASGT helmet by a webbed strap, and the display was positioned over the eye that was not used to aim the M16 rifle. The weight of the HMD is approximately 0.45 kilogram (1.0 lb). The computer that drives the HMD runs at 50 megahertz with 16 megabytes internal dynamic memory and a 540-megabyte hard drive. Trekker™'s two PC card slots contain serial interfaces to communicate with the GPS and the electronic compass.

Figure 2. The Trekker™ system: processor and head-mounted display.

Speakers

In the auditory display condition, position information and other auditory messages were presented through two small speakers installed in the PASGT helmet. These speakers were developed by Electro Voice® (Model 993) and are currently used in the integrated headgear assembly subsystem (IHAS), which is a component of the Land Warrior system. The auditory messages were pre-recorded and were spoken by a female voice. Volume was adjusted to a comfortable level for each participant. All sound levels were kept within allowable limits set forth by the Occupational Safety and Health Administration (OSHA, 1983) and by U.S. Army regulations (U.S. Army Pamphlet 40-501 [U.S. Army, 1991]).

Keypad

In both conditions, computer interface and response to various scenario events were input to a small keypad worn on the participant's belt (see Figure 3). The first two buttons in Rows 1 and 2 of the keypad were used to display visual or auditory position information. These four buttons provided information about the participant's position and orientation with respect to (1) the designated "PATH," (2) his next waypoint or "WP," (3) "TARGET," and (4) other tactical "UNITs." A more detailed description of the visual and auditory displays, effected by depressing these buttons, is provided in Table 1. The last buttons in Rows 1 and 2, labeled "yes" and "no," respectively, were used in response to probe questions that assessed the participants' awareness of the battlefield situation. The "bull's-eye" button located in the last row of the keypad was used to acknowledge that a target was within 50 meters of the participant's position. The three buttons labeled "1" through "3" in the row above the bull's-eye button were used to enter three-digit codes that were painted on the targets. Upon entering this number, the participant depressed the "enter" button. The "cancel" button was used to correct an error in entering the target code or change a response to a probe question.

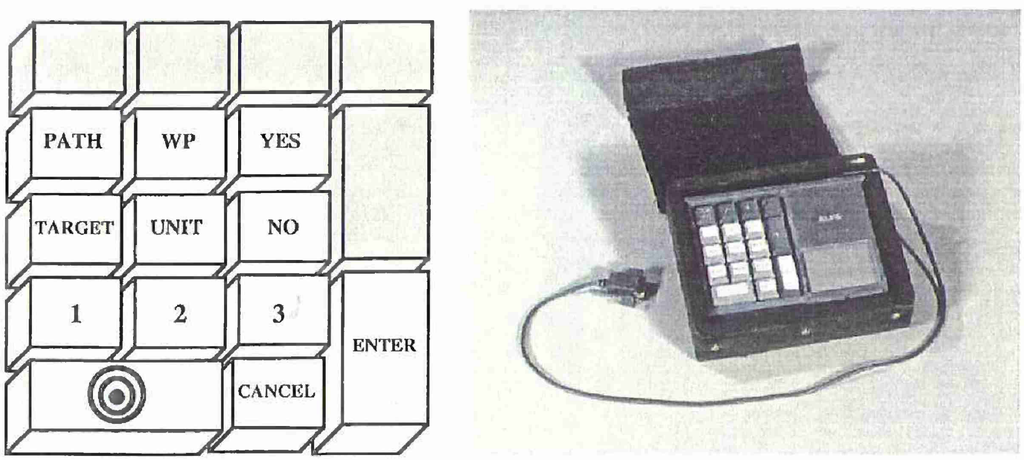
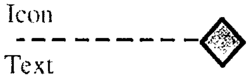
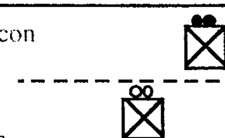
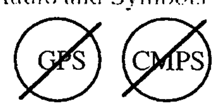


Figure 3. Keypad.

In the visual display condition, information about path, waypoint, target, or unit position was provided in both symbolic and alphanumeric form by the depression of the appropriate button. The symbology was overlaid on a map of the area of operations that

Table 1

Keypad Entries and Information Displayed

INFORMATION TYPE		VISUAL ACTION	VISUAL DISPLAY	AUDITORY ACTION	AUDITORY DISPLAY
PATH	Subject's lateral deviation from path center (meters)	Depress "Path" Button	Icon  Text PATH 25 m Left AZ: 13 °	Depress "Path" Button	"PATH 2 5 meters LEFT. AZIMUTH 1 3 degrees".
	Subject's orientation with respect to path				
WAYPOINT*	Distance from waypoint (meters)	Depress "WP" Button	Icon  Text RNG: 300 m BRG: 11°	Depress "WP" Button	"WAYPOINT 3 0 0 meters. BEARING 1 1 degrees"
	Bearing to waypoint				
TARGET*	Distance from nearest target (meters)	Depress "Target" Button	Icon  Text TARGET RNG: 100 m	Depress "Target" Button	"TARGET 1 0 0 meters"
ENEMY UNIT & FRIENDLY UNIT*	Distance from nearest Enemy and Friendly unit (meters) and their location with respect to path (left or right).	Depress "Unit" Button	Icon  Text ENE RNG: 200 m Left FRD RNG: 100 m Right	Depress "Unit" Button	"Enemy, 2 0 0 meters LEFT. FRIENDLY, 1 0 0 meters RIGHT"
GPS EPE	Estimated Position Error	Automatic (if > 150m for > 1 min)	Text EPE: 150 m	Automatic (if > 150m for > 1 min)	"EPE 150 meters"
EQUIPMENT MALFUNCTION		Automatic	Audio and Symbols 	Automatic	"GPS Down!" "Compass Down!"

* Position with respect to the subject's current location.

depicted the "optimum" straight-line path that the participant must travel to designated waypoints. Only one button could be depressed at a time and only that information requested was provided. The map and the requested information remained displayed for 30 seconds, after which, the display blackened.

Figure 4 depicts the map of the area of operations, including symbology and text information, that was presented in the visual display condition upon depression of the "PATH" button. The "optimum" straight-line path is indicated by solid lines that connect a series of diamond-shaped, waypoint icons. For this study, the path and waypoint icons were displayed for all information requests. Depression of the "PATH" button overlaid an icon that represented the participant's location and orientation with respect to the designated path. This icon is shown as a circle with a pointer. The participant's lateral distance to left or right of the path, as well as his azimuth orientation, was also provided in alphanumeric form to the right of the map display. This text information and iconic representation of the participant's position was only displayed when the "PATH" button was selected. Depression of the "WP" button darkened the waypoint to which the participant was traveling. As for "PATH," distance and heading information to that waypoint was provided to the right of the map. Depression of the "TARGET" button provided symbolic and alphanumeric information about the location of the "target" that was nearest and forward of the participant's position. The targets were three-dimensional wooden silhouettes of enemy personnel that were located at points along the path. A target was shown as an "X" on the map display. Finally, military symbology and alphanumeric information describing the location of the enemy unit and the friendly unit that were nearest and forward of the participant's position were displayed upon depression of the "UNIT" button.

System interrupt messages indicating equipment malfunctions (i.e., "GPS down! Notify lane walker." or "Compass down! Notify lane walker.") were provided auditorily in both display conditions. The participant also received an auditory message when the GPS or compass came back on line (e.g., GPS OK! Notify lane walker). In both display conditions, an auditory alert was provided if the estimated position error (EPE) of the GPS exceeded 150 m for more than 1 minute (i.e., "Warning. GPS EPE greater than 150 meters. Notify lane walker."). This alert was repeated a second time 1 minute after the initial alert. Further alerts were not provided until the EPE of the GPS decreased below 150 m and remained so for more than 1 minute. The participant then heard "GPS EPE normal. Notify lane walker."

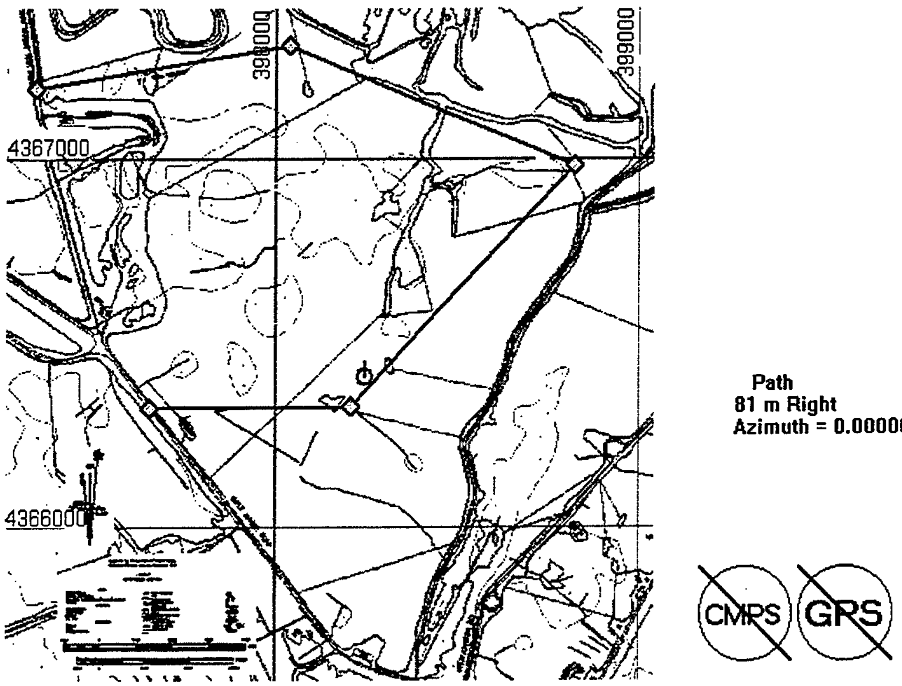


Figure 4. Graphic and alphanumeric information about path position.

In the auditory display condition, the participant received the same information through the speakers installed in the PASGT helmet. As in the visual display condition, the participant depressed one of four buttons on the keypad to receive the desired position information. Only one button could be depressed at a time, and only that information requested was presented. The auditory message containing the requested position information was played once per button push.

In both the auditory and the visual display condition, the frequency at which each type of information was accessed was recorded.

Global Positioning System (GPS) and Electronic Compass

The GPS and electronic compass are components of the DASHER system that were located in the participant's backpack. The GPS and the electronic compass provided position and orientation information in the both the visual and auditory display conditions. The GPS used in this investigation is called the precision lightweight GPS receiver (PLGR). It is a hand-held unit (AN/PSN-11) developed for the military by Rockwell International and when de-encrypted (P[Y] mode), can provide an accuracy of ±10 meters or better. In both conditions, the GPS provided position coordinates that initiated specific task events within designated areas along the path. An electronic compass (C100), developed by KVH (not an acronym) Industries, was used to supply orientation information. The compass is based on magnetic flux sensing technology and has ±0.5° accuracy with a resolution of ±0.1°. Position information supplied by the GPS and azimuth orientation information supplied by the electronic compass were updated at a rate of 1 Hz.

Procedures

Test Participant Screening and Baseline Measures

A visual acuity test at far and near distances was administered to the military volunteers to ensure 20/20 vision in one eye and at least 20/30 in the other eye, corrected or uncorrected. Volunteers were also required to pass tests of color and stereo vision. An audiogram was administered to measure the participants' hearing threshold levels. Test participants completed a questionnaire to obtain pertinent demographic and background information (see Appendix A).

Stress measures and a cognitive performance test battery were administered to familiarize the participants with the procedures to be followed in the collection of these data during training and testing and to obtain baseline measures. The stress measures included the Salivary Amylase Field Test (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996) and a battery of stress questionnaires (see Appendix B). Cognitive performance was measured using the Cognitive Performance Assessment for Stress and Endurance (CPASE) (Mullins, 1996) described in Appendix C.

During this period, the participants received instruction in the assessment of their workload experience in accordance with the prescribed procedures of the National Aeronautics and Space Administration-Task Load Index (NASA-TLX). The NASA-TLX (Hart & Staveland, 1988) uses rating scales to assess mental, physical, and temporal demands, performance, effort, and frustration. In this technique, a weight is initially obtained for each of the six workload factors, based on the subject's responses to pair-wise comparisons among these factors. In these comparisons, the six factors are presented in 15 possible pairs and, for each pair, the subject was asked to circle the factor that he perceived to contribute more to his workload experience. The subject then completed rating scales that provide a measure of the magnitude of the workload for each factor. Those factors perceived by the subject to be most important in his workload experience are given more weight in computing the overall workload score. Definitions of each of the six workload factors that were assessed, the pair-wise comparisons, and rating scales are provided in Appendix D.

Training

The duration of training and testing for each of the 12 military participants was 5 days. Pre-screening was performed and baseline measures were obtained on the first day of the study. Training and testing in one of the two display conditions were conducted on Day 2 and Day 3, respectively. Training and testing in the second condition were conducted on Day 4 and Day 5. Two participants were trained and tested at a time.

In each condition, training included both classroom and field instruction during which the participants were trained to a point at which they achieved an asymptote in the performance of land navigation and target detection tasks using visually or auditorily displayed information. The Salivary Amylase Field Test, stress questionnaires, and the CPASE test battery were administered immediately before and after training in each condition.

During classroom training in each display condition, the participants wore the DASHER system and PASGT helmet configured to display information in either the auditory or visual modality, as appropriate. For this portion of the training, the participant was seated on a rotating stool with his back to a computer monitor that displayed the training path. The instructor, aided by icons denoting scenario events, "walked" a cursor that represented the participant along the path and coached the participant in the use of the keypad in accessing navigational and other tactical information. Instruction also included practice in responding to probe questions and adjusting azimuth orientation with respect to the designated path and waypoints.

The participant then completed a minimum of three runs on the actual training path. The training path consisted of three 200-meter segments, making a total path length of 600 meters. In each of the three segments, the participants performed all tasks that they would perform during testing. Each participant was accompanied on the training path by a "lane walker." This lane walker also accompanied the participant throughout testing in each display condition. The lane walker was equipped with a hand-held GPS receiver, a map, and a lensatic compass. The primary purpose of the lane walker was to ensure the test participant's safety. Other functions included equipment troubleshooting and the administration of stress tests and the cognitive test battery.

Testing

During the field experiment, the performance of each of the 12 participants was measured in each of the two display conditions (visual and auditory). During testing, two participants navigated in the same condition at the same time on the same unmarked test path but in opposite directions. The direction in which these participants navigated the test path in the second experimental condition was reversed.[1] The order of presentation of display conditions and path direction was counterbalanced as shown in Table 2.

Table 2

Design Matrix and Counterbalancing Scheme

Subject No.	Display condition (visual "1" and auditory "2") Path direction (forward "F" and reverse "R")	
1	1F	2R
2	1R	2F
3	2F	1R
4	2R	1F
5	1F	2R
6	1R	2F
7	2F	1R
8	2R	1F
9	1F	2R
10	1R	2F
11	2F	1R
12	2R	1F

The test path is shown in Figure 5. The total length of the path was 3 kilometers, and the path consisted of four segments or legs of different lengths that intersected five waypoints: WP1 (start point), WP2, WP3 (midpoint), WP4, and WP5 (end point). The lengths of the path legs were 550, 700, 850, and 900 meters. The first 100 meters of Leg 1 consisted of a few dense patches of thorny vegetation, which the participants could circumvent as desired. Vegetation density for most of Leg 1 was mild to moderate. Leg 2 was the mildest segment of the course, characterized by open woods with tall, well-spaced trees that allowed good visibility at distances. Ground vegetation, including thorny shrubs, thickened about 50 meters before Leg 3. Briars were thickest and visibility poorest in Leg 3 which is bordered by marsh that is generally impassable. In Leg 4, the vegetation varied in type and density, and visibility conditions were mixed. This latter leg of the path was generally less severe than Leg 3.

[1]Lane walkers who walked the path frequently during a previous investigation could not recall the path even though the path was walked in the same direction on all occasions.

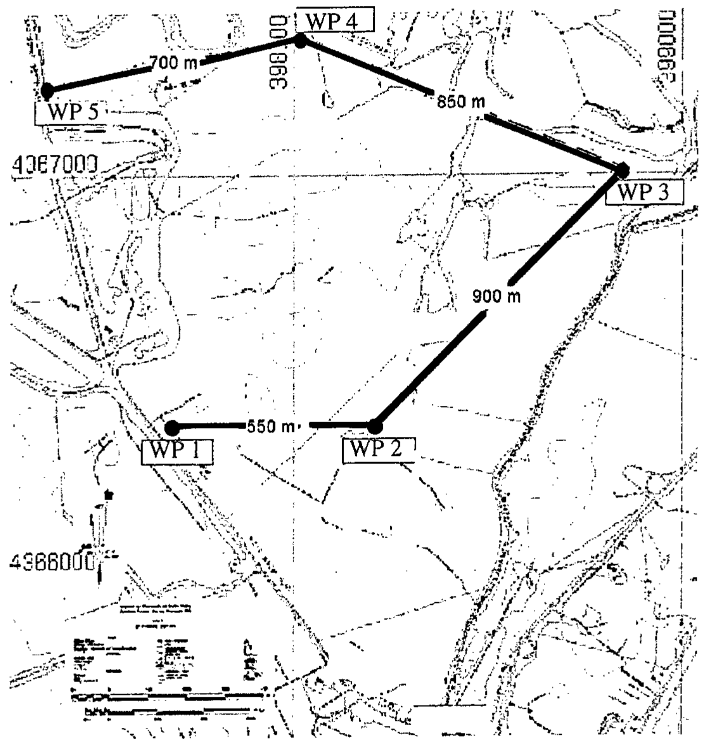


Figure 5. Test path with waypoint positions and leg lengths.

The terrain through which the path ran was flat with elevation contours of 2 to 3 feet. The ground was covered with fallen trees and branches which, in some areas, were concealed by grass approximately 8 inches tall. There were some small streams along the path and marshy areas with standing water. Except for a few short, muddy sections of path that lacked ground cover, the hardy grasses and vegetation that grow in this area tend to recover quickly from footsteps, revealing little evidence of previous travelers.

Before testing in each display condition, the participants were administered the Salivary Amylase Field Test, stress questionnaires, and the CPASE test battery. The participants were then accompanied by their lane walkers toward the point of departure. Within ±20 meters of the starting point of the test path, each participant received an auditory message stating that the initial waypoint had been reached and to notify the lane walker. The lane walker reminded the participant of the mission and the tasks that had to be performed. The participant was also reminded that all tasks were equally important, as were the speed and accuracy with which he performed these tasks. A more detailed description of these tasks and the instructions that the participant received in the performance of the tasks follows.

Navigation

The participant was instructed that speed and accuracy were equally important when traveling from waypoint to waypoint and to maintain a position on a straight-line course, deviating only as far as necessary to avoid obstacles. In case of a detour, the participant was told to return to the path as soon as possible and resume a straight-line course to the next waypoint. At any time, in both display conditions, the participant could obtain information about his distance from path center, along with his azimuth orientation, by depressing the "PATH" button. In both conditions, the lane walker provided one verbal warning at 20, 40, and 60 meters' deviation from the path. At 60 meters' deviation from the path, the lane walker guided the participant back to path center. The primary reason for these warnings was participant safety; however, the number of warnings received at each of the three levels of deviation were recorded. The absolute position of the participant was recorded once a second, along with the EPE of the GPS located in the participant's backpack. Navigation accuracy was determined, based on the actual distance the participant traveled in each leg of the path. Measures of travel velocity were computed by dividing the distance the participant traveled in each leg by the time required to travel the leg. The time spent at each WP was not included in calculations of time, nor was any time that might have been spent in diagnosing and resolving equipment problems.

Target Acquisition

Five three-dimensional wooden silhouettes of enemy personnel were positioned at four random distances on each leg of the path (a total of 20 targets). In both display conditions, the participant obtained information about the distance of the nearest target beyond his position by depressing the "TARGET" button on his keypad. The participant was instructed to monitor the position of these targets to determine when a target was 50 meters from his position. When a target was 50 meters from his position, the participant was instructed to depress the "bull's-eye" button on his keypad. The distance of the target from the participant's position at button depression and the EPE of the GPS were recorded. The participant was then required to find and "destroy" the target as quickly as possible. Each wooden silhouette was marked with a different three-digit number that the participant entered via the keypad. Entry of the correct number verified that the target was seen. In both conditions, if the keypad entry was correct, the participant was provided auditory feedback in the form of an explosion. If the keypad entry was incorrect, the participant heard a ricochet sound. The time to destroy a target was recorded from the time the participant was 50 meters from the target until the time the correct keypad entry was completed. Data were also collected for targets that the participant destroyed but failed to acknowledge as being 50 meters from his position.

Situational Awareness (probe questions)

One presumed advantage of HMDs is the increased availability of information to the wearer. To test this hypothesis, a measure of awareness was obtained using probe questions. This method of measuring awareness was first used by Marshak, Kuperman, Ramsey, Wilson (1987) and refined by Amburn (1994). Awareness relates to the information that an individual can recall from his or her short-term memory. Typically, specifics are not easily recalled. Therefore, in the probe question method, the question protocol is limited to a recognition response of a simple "yes" or "no." The yes-no format also allows analysis of responses using signal detection theory (Green & Swets, 1966). A simple fact in short-term memory is treated like a signal embedded in the noise of other memories. The sensitivity measure (d-prime [d']) measures the salience of information in short-term memory. In the present study, 20 probe questions (five questions per path leg) were presented to the participant by computer-generated audio at pre-determined area coordinates along the path. These questions were used to assess the participant's awareness of information provided in the visual and auditory displays. The questions queried the participant about his position with respect to waypoints, targets, and other units. (For example: "Is there an enemy unit within 200 meters to your right?") The participant responded to these questions by depressing the "yes" or "no" buttons on the keypad. The participant was not able to access either the auditory or visually displayed information until he had responded to the probe question. The responses to the probe questions were treated as an assessment of information available in the participant's memory and were analyzed using the signal detection sensitivity statistic (d').

Immediately upon completing the test path, the participant was administered the CPASE test battery, the Salivary Amylase Field Test, and stress questionnaires. Upon returning to the command center, the participant assessed his workload experience using the NASA-TLX. Each participant then completed a questionnaire to obtain information about the frequency of use of the auditory and visual displays and any problems he may have experienced. After testing was completed in both display conditions, a post-test questionnaire was administered to obtain information about the participant's display preferences. The post-test questionnaires are provided in Appendix E.

RESULTS

Land Navigation

Post Processing of Position Data

Raw position data were logged from the GPS using the P(Y) precision military signal. The precision signal can achieve ±10 meters or better accuracy without needing a differential GPS base station. However, these raw data contained considerable random noise. Processing the raw data was necessary to improve resolution.

A simple moving average was employed to filter (eliminate) the random noise. Each data point was replaced with the average of the current point with five earlier and five later samples. The size of this "window" was empirically determined, based on examining different window sizes of pilot data. Very large excursions caused by momentary loss of GPS satellite data, as well as excursions greater than 70 meters from the path, were excluded from the data analysis. These latter excursions were rare, given that the soldier was directed back to the path at deviations of 60 meters.

Navigational Error

The four legs within the 3-kilometer test path varied in length (namely, 550 m, 700 m, 850 m, and 900 m). To obtain a standardized measure of performance on these different leg lengths, the actual distance traveled by the participant was divided by the length of the leg. This allowed analysis of path leg as an independent variable. This standardized measure of distance traveled was computed for each participant and subjected to a repeated measures analysis of variance (ANOVA) with display condition (visual and auditory) and path leg (Leg 1 through 4) as within-subjects effects. The results of the ANOVA, presented in Table 3, indicate that there were no differences between display conditions. Figure 6 shows the mean distance traveled by leg, standardized by leg length, for the visual and auditory display conditions. These data, along with standard errors, are provided in Appendix F.

Velocity

Measures of travel velocity were obtained for each equipment condition by dividing the distance traveled within each leg of the path by the time to navigate these legs. Velocity measures were subjected to an ANOVA like the one performed on distance traveled. The results of this analysis are presented in Table 4.

Table 3

ANOVA Results of Standardized Distance Traveled

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
DISPLAY	1	.003	.003	.119	.737
SUBJ*DISPLAY	10	3.273	.327		
LEG	3	1.224	.408	.734	.540
SUBJ*LEG	30	16.671	.556		
DISPLAY*LEG	3	1.198	.399	1.906	.150
SUBJ*DISPLAY*LEG	30	6.286	.210		

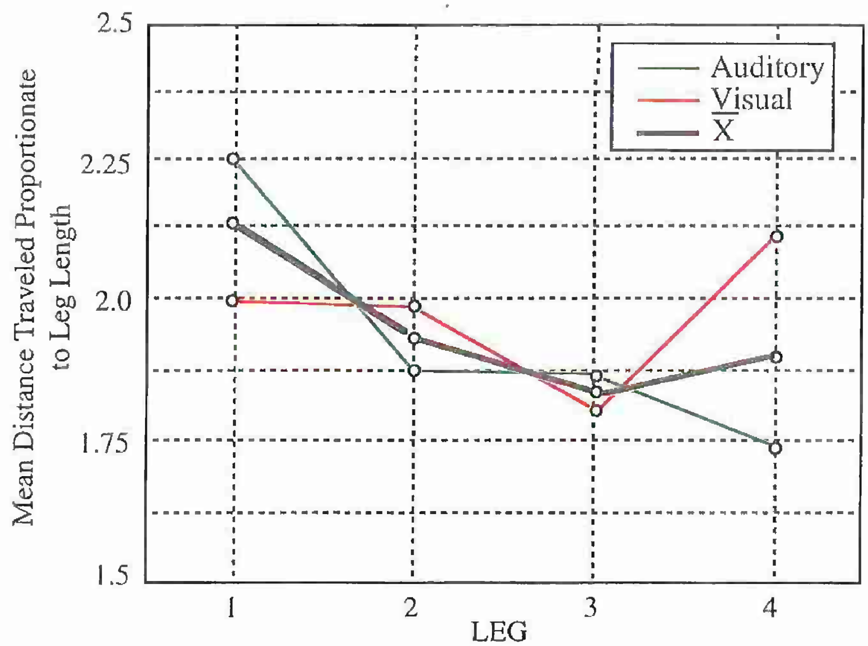


Figure 6. Mean distance traveled (standardized by leg length) by display condition and path leg.

Differences between display conditions in travel velocity were not statistically significant. However, a main effect was found for path leg, $F(3,30) = 3.66, p = .023$, with mean velocities, as depicted in Figure 7, of 53.28 m/min (Leg 1), 58.16 m/min (Leg 2), 48.17 m/min (Leg 3), and 45.47 m/ min (Leg 4). These mean velocities were subjected to dependent *t* tests. The results indicated that the main effect for path leg was attributable to a significant decrease in velocity between Leg 2 and 3 ($t(10) = 2.46, p < .033$) and between Leg 2 and Leg 4 of the path ($t(10) = 2.88, p < .016$). This finding reflects differences between these legs in vegetation density, where Leg 2 was the mildest of the legs, followed by Leg 1 and Leg 4. Leg 3 was the most difficult leg to navigate in both test paths. All other effects failed to reach significance at the .05 level of confidence.

Table 4

ANOVA Results of Travel Velocity

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
DISPLAY	1	573.003	573.003	1.940	.194
SUBJ*DISPLAY	10	2956.411	295.641		
LEG	3	2085.530	695.177	3.666	.023
SUBJ*LEG	30	5688.392	189.613		
DISPLAY*LEG	3	539.593	179.864	1.253	.308
SUBJ*DISPLAY*LEG	30	4307.241	143.575		

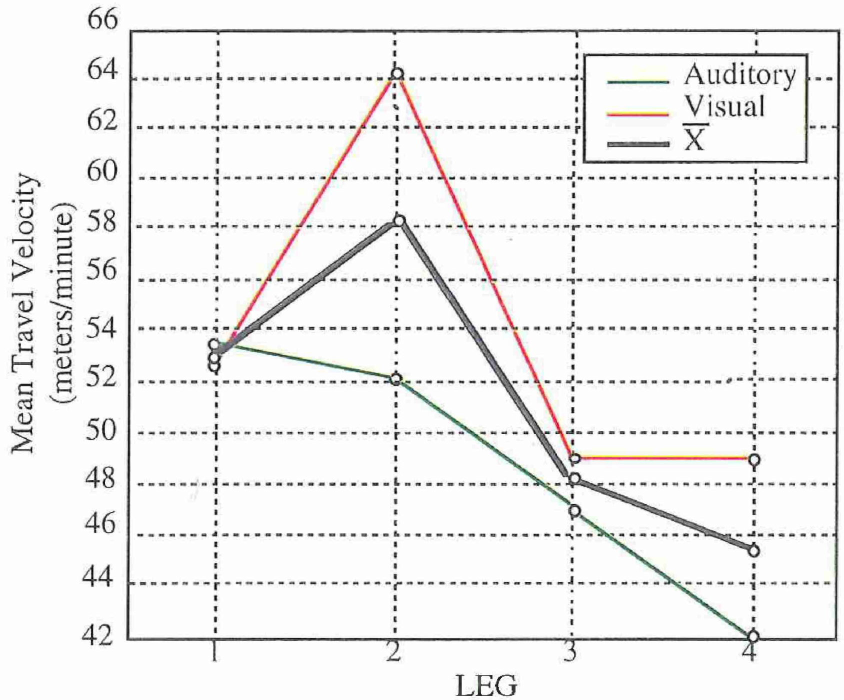


Figure 7. Mean travel velocity by display condition and path leg.

Target Acquisition

Number of Targets Destroyed

The mean number of targets destroyed was subjected to a repeated measures ANOVA with display condition and path leg as within-subject effects. The results of the analysis, shown in Table 5 and illustrated in Figure 8, indicate that there were no significant differences between display conditions where the mean number of targets destroyed by leg was 4.46 in the visual condition and 4.25 in the auditory mode. A significant main effect, however, was found for path leg ($F(3, 33) = 8.932, p < .001$) with mean number of targets destroyed of 4.54 (Leg 1), 3.96 (Leg 2), 4.83 (Leg 3), and 4.08 (Leg 4). The results of dependent *t* tests revealed that this effect was attributable to the greater number of targets destroyed on Leg 1 than on Leg 2 of the path, $t(11) = 3.38, p = .006$, and to the greater number of targets destroyed on Leg 3 than on Leg 2, $t(11) = -4.70, p < .001$, and Leg 4, $t(11) = 3.95, p = .002$. The difference between Leg 2 and Legs 1 and 3 may reflect the positioning of a target on Leg 2 that reduced its detectability. The greater number of targets destroyed on Leg 3 than in Leg 4 may reflect closer adherence to the path on Leg 3 so as to avoid more difficult terrain, and thus the greater likelihood of encountering targets. All other effects failed to reach significance at the .05 level of confidence.

Table 5

ANOVA Results of Number of Targets Destroyed

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
DISPLAY	1	1.042	1.042	.676	.429
SUBJ*DISPLAY	11	16.958	1.542		
LEG	3	11.875	3.958	8.932	.000
SUBJ*LEG	33	14.625	.443		
DISPLAY*LEG	3	2.375	.792	1.061	.379
SUBJ*DISPLAY*LEG	33	24.625	.746		

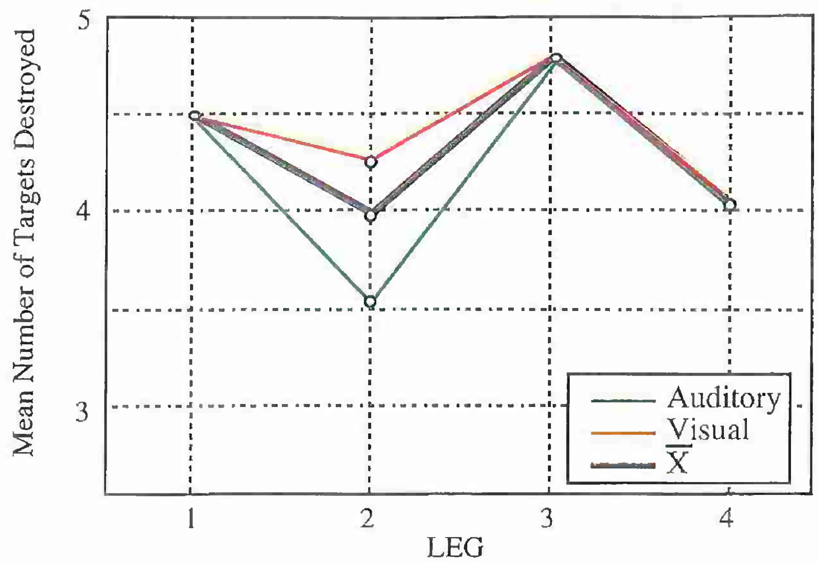


Figure 8. Mean number of targets destroyed by display condition and path leg.

Time to Destroy Targets

Time to destroy a target was computed from the time the participant was 50 meters from the target, as determined by the GPS, to the time the participant entered a three-digit number that was painted on the target. The mean times to destroy targets were subjected to an ANOVA. The results of this analysis are presented in Table 6 and illustrated in Figure 9.

Table 6

ANOVA Results of Time to Destroy Targets

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
DISPLAY	1	2126.472	2126.472	.641	.440
SUBJ*DISPLAY	11	36467.879	3315.263		
LEG	3	33970.350	11323.450	3.135	.039
SUBJ*LEG	33	119208.740	3612.386		
DISPLAY*LEG	3	15163.395	5054.465	1.579	.213
SUBJ*DISPLAY*LEG	33	105647.710	3201.446		

A significant main effect was found for leg (F(3, 33) = 3.135, $p = .039$) with mean times of 74.28 sec (Leg 1), 81.94 sec (leg 2), 122.64 sec (Leg 3), and 102.19 sec (Leg 4). These mean times were subjected to dependent t tests. The results of these analyses revealed that the main effect for path leg was attributable to a difference in time to destroy targets between Leg 1 and Leg 3 of the path, t (11) = - 2.26, $p = .044$. This finding reflects differences between Legs 1 and 3 in vegetation density and the distances from which targets could be seen. All other effects failed to reach significance at the .05 level of confidence.

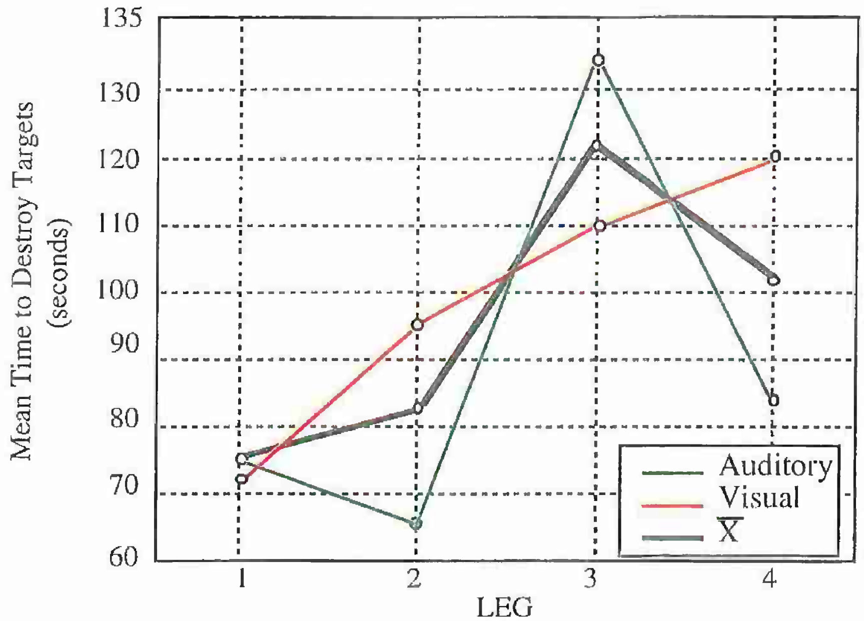


Figure 9. Mean time to destroy targets by display condition and path leg.

Information Access

Overall, significant differences were found among all four types of information in the frequency at which the information was accessed ($p < .001$). Information about path position was accessed most frequently (452 times), followed by information about target (159 times), waypoint (97 times), and unit position (33 times).

The frequencies at which each type of information was accessed (path, waypoint, target, and unit) were subjected to an ANOVA with display condition (auditory and visual) and path leg (Leg 1 through 4) as within-subject effects. The results of this analysis are presented in Table 7.

Differences between display conditions in the frequency at which each of the four types of information was accessed were not statistically significant. However, a significant main effect was found for leg in the frequency of access to information about target position (F (3, 33) = 8.75, $p < .001$). This effect merely reflects differences in leg length, where information about target position was accessed less frequently on the shortest leg of the path (Leg 1) by comparison to longer legs (Legs 2, 3, and 4). A significant Display x Path Leg interaction was found in the frequency of access to information about waypoint position (F (3, 33) = 4.09, $p = .014$). Here, too, this interaction primarily reflects differences in leg length, where differences between Legs 1 and 2 in the frequency at which this information was accessed were significant in the auditory mode but not in the visual display condition. All other effects failed to reach significance at the .05 level of confidence.

Table 7

ANOVA Results of Frequency of Access of Information

Source	Measure	DF	ANOVA SS	Mean Square	F Value	Pr > F
DISPLAY	Path	1	6160.010	6160.010	3.414	.092
	Target	1	356.510	356.510	4.199	.065
	Unit	1	41.344	41.344	2.387	.151
	WP	1	7.594	7.594	.069	.797
Error (DISPLAY)	Path	11	19847.115	1804.283		
	Target	11	933.865	84.897		
	Unit	11	190.531	17.321		
	WP	11	1204.281	109.480		
LEGS	Path	3	1791.365	597.122	.916	.444
	Target	3	648.198	216.066	8.755	.000
	Unit	3	24.365	8.122	2.647	.065
	WP	3	84.198	28.066	1.017	.398
Error (LEGS)	Path	33	21502.510	651.591		
	Target	33	814.427	24.680		
	Unit	33	101.260	3.068		
	WP	33	910.927	27.604		
LEGS*DISPLAY	Path	3	2879.115	959.705	1.034	.390
	Target	3	56.865	18.955	.416	.743
	Unit	3	9.115	3.038	.786	.510
	WP	3	412.365	137.455	4.097	.014
Error (LEGS* DISPLAY)	Path	33	30615.260	927.735		
	Target	33	1504.260	45.584		
	Unit	33	127.510	3.864		
	WP	33	117.260	33.553		

Situational Awareness (Probe Questions)

"Yes" and "no" answers to probe questions were graded as hits, false alarms, misses, or correct rejections, which are defined as follows:

Hit: Answered "yes," and "yes" was correct
False alarm: Answered "yes," and "no" was correct
Miss: Answered "no," and "yes" was correct
Correct rejection: Answered "no," and "no" was correct

From these scores, conditional probabilities of the participant making a particular response were determined as follows:

$$p(\,hit\,) = \frac{number\ of\ hits}{number\ of\ hits\ \ +number\ of\ misses}$$

$$p(\,false\ alarm\,) = \frac{number\ of\ false\ alarms}{number\ of\ false\ alarms\ \ +number\ of\ correct\ rejections}$$

Based on these probabilities, measures of sensitivity (d') were computed, based on the theory of signal detection using the following formula:

$$d' = z(p[hit]) - z(p[false\ alarm])$$

It was assumed that the information requested in the probe questions was equally probable and normally distributed.

Mean d's for each of the participants by display condition are shown in Table 8. The larger the d', the greater the probability that the participant responded correctly and less likely by chance. Mean d's close to zero indicate fewer correct responses and the greater likelihood that correct or incorrect responses were made by chance.

The mean d's for the visual and auditory display conditions shown in Table 8 were subjected to a dependent *t* test. The results of the analysis indicate significant differences between the two display conditions ($t\,(11) = -4.509$, $p = .001$). This finding suggests that the participants' sensitivity to the information was greater when the information was presented visually than when the information was presented auditorily.

Table 8

Signal Detection (d') for Visual and Auditory Conditions on Probe Questions

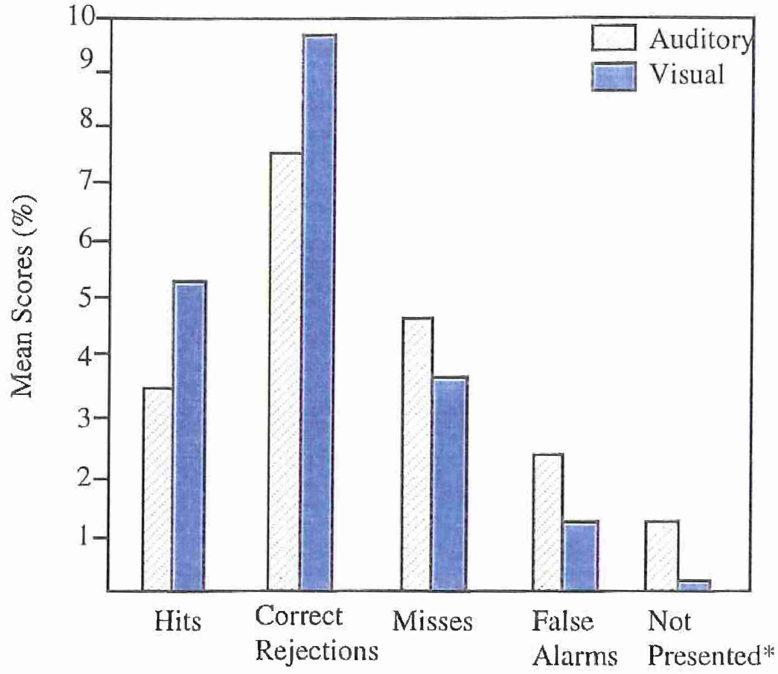
Subject	Auditory	Visual
1	0.2947	3.5027
2	0.1356	2.8369
3	1.1603	0.5280
4	-0.2766	1.4603
5	1.1837	2.9393
6	0.7294	1.4603
7	0.2333	0.9673
8	-0.4632	2.0828
9	0.0845	3.8291
10	0.1252	1.6533
11	0.4679	0.4679
12	0.9922	3.5027
M=	0.3889	1.2457
SD=	0.5343	1.2574
	p(t) = -4.509	correlation = -.022

The mean percentages of hits, misses, correct rejections, and false alarms by display condition are illustrated in Figure 10. In the visual mode, the mean percentage of hits was greater than the mean percentage of misses, and the mean percentage of correct rejections was greater than false alarms. In the auditory mode, the mean percentage of correct rejections was still greater than the mean percentage of false alarms; however, the mean percentage of misses was greater than hits. No significant correlations were found between the accuracy of the participant responses to the probe questions and the frequency at which the participants accessed associated position information.

Stress

Confidence Levels

The Situational Self-Efficacy (SSE) scale asks respondents to rate their level of confidence in their ability to perform well from 1 ("not at all confident") to 10 ("extremely confident"). An analysis of levels of self-efficacy for the visual (Mean = 8.7) and auditory conditions (Mean = 8.4) indicated that the participants felt confident in their ability to perform their tasks regardless of display modality (t (1,10) = 1.102, p = .296).



* Beyond area coordinates.

Figure 10. Mean scores (percent) on probe questions by display condition

Psychological Stress Levels

The Multiple Affective Adjective Checklist-Revised (MAACL-R) consists of five subscales which are typically analyzed together. These subscales are anxiety (sense of uncertainty), depression (sense of failure), hostility (sense of frustration), positive affect (sense of well-being), and dysphoria (negative affect). A three-way multiple analysis of variance (MANOVA) (condition x session x subscale) was conducted to compare stress perception levels between the visual and auditory display conditions. The results indicated that there were no significant differences between conditions (F (11) = .088; p = .772) or subscales (Wilks' λ = .458; F (8,4) = 2.365; p = .142). However, a significant difference was found between the pre- and post-sessions, F (11) = 8.110; p = .016. The effects of session are related to the subscales of hostility (F (23,1) = 5.915; p = .023) and dysphoria (F (23,1) = 5.924; p = .023).

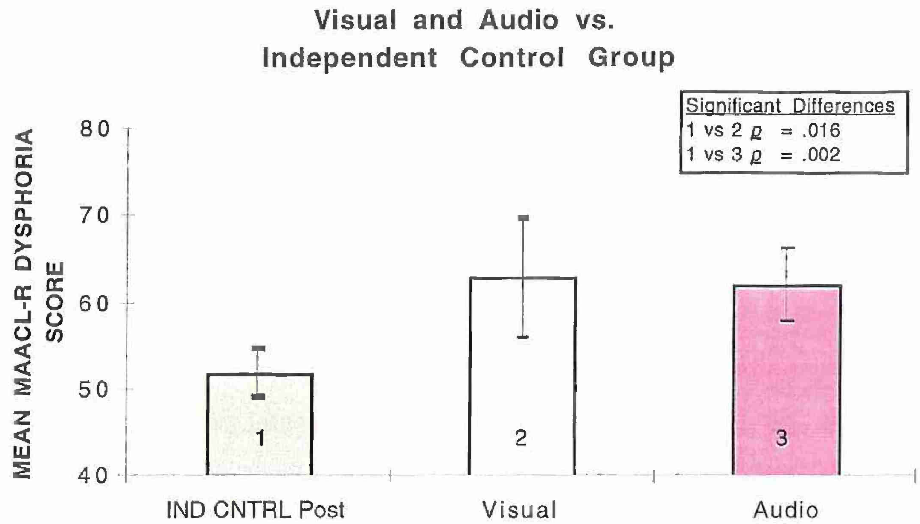
Two additional stress perception measures, the Subjective Stress Scale and Rating of Events-Specific, provide a more general assessment of stress and were analyzed in a separate three-way MANOVA (condition x session x measure). The results indicated that there were no significant differences between conditions (F (10,1) = .894; p = .367), sessions (F (10,1) = 2.159; p = .172), or measures (F (10,1) = 660.011; p = .391).

In order to estimate the relative amount of stress experienced by the participants, the psychological data were compared with data from an Independent Control Group (INDCNTRL) that includes one pre-measurement and one post-measurement. This procedure was followed in accordance with standard experimental methodology, which recommends comparisons with a group that is not manipulated by the study in any way but is measured during time periods that correspond to those of the experimental group (Myers & Hansen, 1980). The INDCNTRL consists of men who were given identical stress perception measures during normal workdays when they were experiencing no unusual stress and represents a relatively low stress level or a condition of no stress.

A four-way MANOVA (condition x session x measure x group) was conducted to compare the measures of the MAACL-R between the visual and auditory display conditions with the INDCNTRL. The results revealed a four-way interaction of condition x session x measure x group (Wilks' λ (= .653; F (30,4) = 3.990; p = .010), a three-way interaction of condition x session x measure (Wilks' λ (= .653; F (30,4) = 3.990; p = .010), and a two-way interaction of measure x group (Wilks' λ (= .619; F (30,4) = 4.615; p = .005). An ANOVA was performed on each MAACL-R subscale to test for the effect of these interactions. As illustrated in Figure 11, post-test stress levels for both the visual and the auditory display conditions were significantly higher than those of the independent control group. A four-way MANOVA (condition x session x measure x group) was conducted to compare responses on the Subjective Stress Scale in the visual and auditory display conditions with the those of the INDCNTRL. No significant differences were found (Wilks' λ = .815; F (8,4) = .975; p = .331).

Salivary Amylase Field Test

A repeated measures ANOVA was conducted on salivary amylase across four sessions: pre-visual (Mean = 246), post-visual (Mean = 270), pre-auditory (Mean = 175), and post-auditory (Mean = 245). No significant differences were found between conditions (F (11,1) = 3.683; p = .081), or sessions (F (11,1) = 3.433; p = .091). The state salivary amylase was compared to the baseline collection (Mean = 263) and no significant differences were found between baseline and the visual condition (Wilks' λ = .607; F (10,2) = .905; p = .607) or between baseline and the auditory condition (Wilks' λ = .628; F (10,2) = 2.967; p = .097).



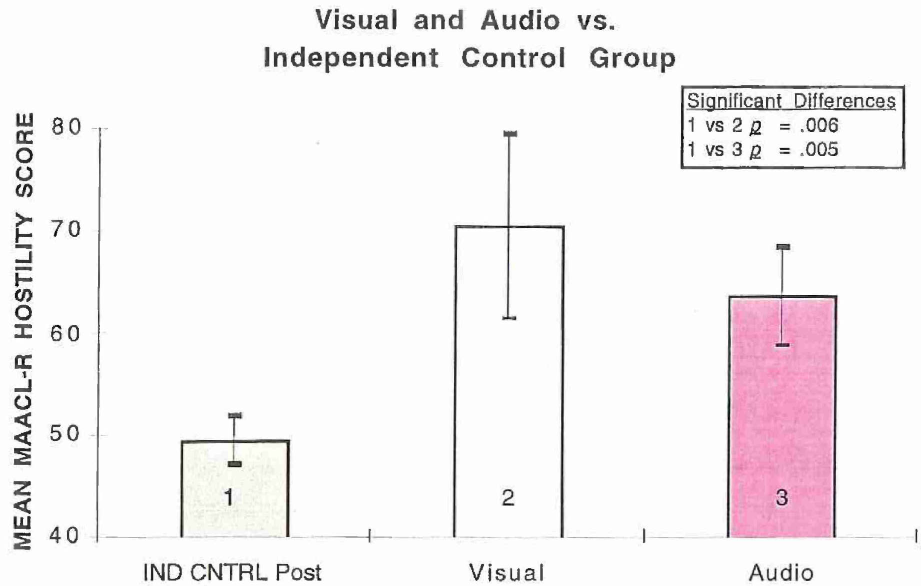


Figure 11. Comparison of mean post-stress MAACL-R dysphoria and hostility scores (±SEM) for the visual and audio display condition with those in the independent control group.

Cognitive Performance

Cognitive performance tasks included verbal memory, logical reasoning, addition, and spatial rotation. To delineate performance differences, each test was evaluated as to the number of items completed correctly. A separate session (pre- and post-test) by condition (auditory and visual) repeated measures ANOVA was computed for each performance variable. Baseline measures were not included in these ANOVAs. Shifts from baseline were evaluated by computing a MANOVA for each performance variable across baseline, pre- and post-test auditory, and pre- and post test visual condition.

Verbal Memory

This short-term memory test required written recall of 12 single and double syllable words. No significant differences were found for condition or session in the performance of this cognitive task.

Logical Reasoning

The logical reasoning task (Baddeley, 1968) involved 32 evaluations of a phrase describing letter pair order and corresponding letter pairs. Each evaluation was judged as "true" or "false." Test participants had 1 minute to respond to as many of the items as possible. No significant differences were found for condition or session in the performance of this cognitive task.

Addition

For this computation task, the test participants were given 30 seconds to complete 15 problems, adding two randomly selected three-digit numbers together. No significant differences were found for condition or session in the performance of this cognitive task.

Spatial Rotation

The test participants' performance of the spatial rotation task involved pattern recognition and figure rotation. The participants had 2 minutes to respond to the 18 evaluations presented in this task. The ANOVA indicated a significant main effect for sessions ($F\ (1,11) = 11.04$; $p < .007$). Pairwise comparisons indicate that the visual post-test measure (Mean = 14.6) was significantly higher than the visual pre-test measure (Mean = 12.4) and the auditory pre-test measure (Mean = 12.8). Also, the visual pre-test measure differed significantly from the auditory post-test measure (Mean = 13.8). These session effects were also reflected in the baseline analysis, where the baseline measure (Mean = 11.5) was significantly lower than the auditory pre-test and post-test measures.

Workload (NASA-TLX)

Weighted ratings for each of the six workload factors and an overall weighted workload score were calculated for each participant in each display condition in accordance with the procedures prescribed by the NASA-TLX. Figure 12 depicts the composition of the weighted workload score. In this chart, the width of each subscale bar reflects the importance (weight) of each factor derived from the participants' responses in pair-wise comparisons of the six workload factors. The height of the bars represents the magnitude (rating) of these factors derived from the participants' scaled ratings. The overall workload score shown to the right of the subscale bars represents the average area of these bars.

The mean weighted ratings for each workload factor and the overall weighted score were computed for each condition and were analyzed using paired sample *t* tests. The results of the analyses indicated that there were no significant differences between the auditory and visual display conditions in the participants' ratings of workload.

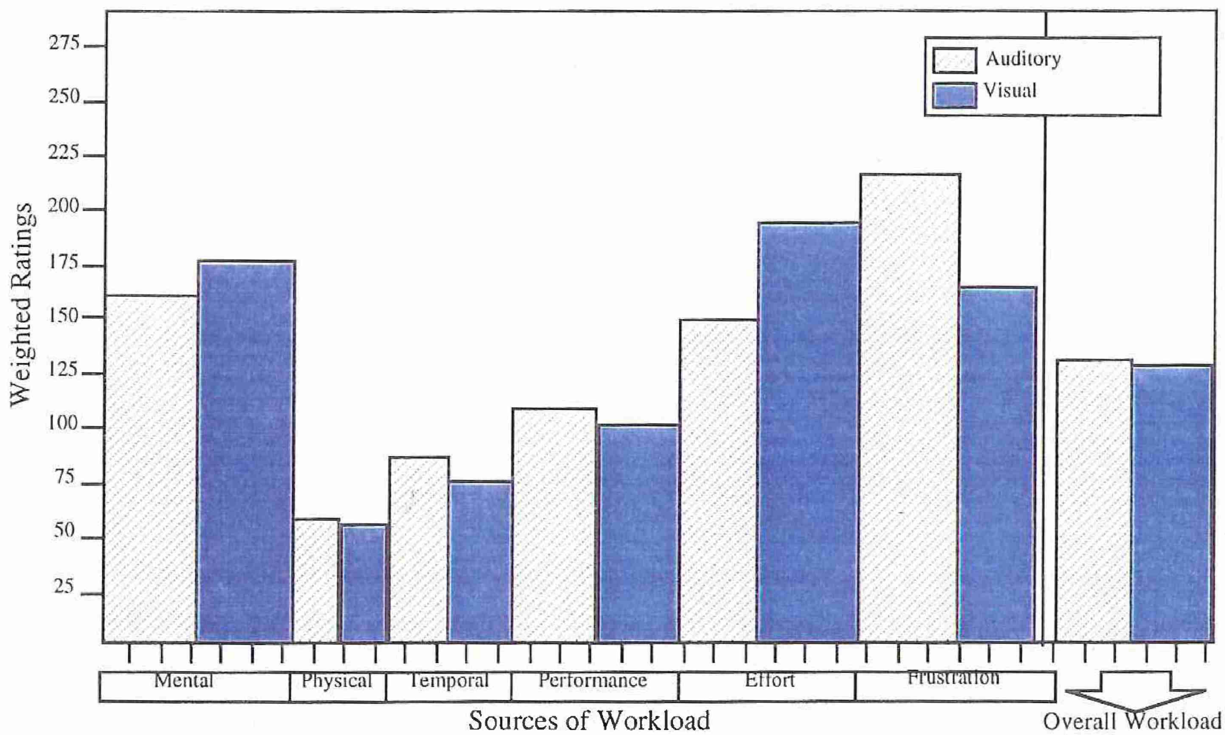


Figure 12. Mean weighted ratings of sources of workload and overall workload experience.

Pearson's correlations were computed to examine the relationship between sources of workload. In the auditory mode, a significant correlation was found between the participants' perception of how well they performed and their level of frustration ($r(10) = .692, p = .015$). This finding indicates that the poorer the participants thought they performed, the higher their levels of frustration. In the visual mode, as frustration increased, so did the participants' overall experience of workload ($r(10) = .775, p = .003$). In the auditory mode, a relationship was also found between the participants' perception of time demands and overall workload ($r(10) = .648$, $p = .023$). This finding suggests that as time demands increased, the participants' experience of overall workload also increased.

Workload and Task Performance

Correlations were computed to examine the relationship between workload factors and the participants' performance of land navigation and target acquisition tasks. In the auditory mode, a relationship was found between time to destroy targets and physical workload ($r\ (10) = .738, p = .006$), which indicates that as the participants' experiences of physical workload increased, so did the time to destroy targets. In the visual mode, a negative correlation was found between time to destroy targets and temporal workload ($r(10) = -.656, p = .02$). This finding indicates that as time demands increased, time to destroy targets decreased. No relationships were found between sources of workload and navigational performance in either display condition.

Workload and Cognitive Performance

Pearson's correlations were also computed to evaluate the relationship between sources of workload and cognitive performance. Pre-test scores were subtracted from the corresponding post-test scores to determine a difference score for performance measures. This delta was used in the correlation analyses with the NASA-TLX scores. Logical reasoning for the auditory condition and the visual condition were significantly correlated with temporal workload, ($r\ (10) = .711, p < .01$) and ($r\ (10) = -.696, p < .01$), respectively. These findings indicate that in the auditory mode, as time demands increased, post-test scores on the logical reasoning tended to be higher than pre-test scores; whereas in the visual mode, as time demands increased, post-test scores on the logical reasoning task tended to be lower than pre-test scores. The improvement in post-test scores in the auditory task may be attributable to the additional practice that participants received in processing the verbal information.

Significant correlations were also found between logical reasoning and frustration in the visual condition ($r\ (10) = -.630, p = .028$) and between logical reasoning and physical workload in the auditory condition (r (10) = -.624, p =.030). These findings indicate that in the visual mode, as frustration increased, post-test scores on the logical reasoning task tended to be lower than pre-test scores. Similarly, in the auditory mode, post-test scores on the logical reasoning task tended to degrade as the participants' experience of physical workload increased.

Mental workload correlated with addition performance in the visual condition, r (10) = -.670, p = .017, and spatial rotation correlated with temporal workload in the auditory condition, r (10) = -.620, p = .023. In the visual condition, as the participants' ratings of mental workload increased, post-test performance of the addition task tended to be lower than pre-test scores. Similarly, in the auditory mode, as time demands increased, post-test performance of the spatial rotation task tended to degrade.

Questionnaire Responses and Participant Preferences

Participant responses on the post-run questionnaires indicated that they did not have any difficulties in seeing or hearing and understanding the information provided in each of the two display modes. Performance of navigation and target acquisition tasks was rated as "easy" when information was presented visually but "neither easy nor difficult" when information was presented auditorily. By contrast to measures of keypad input reported before, participants estimated that they accessed information about waypoint and unit position more often than they accessed information about path or target position in both display conditions.

In the auditory mode, 4 of the 12 participants preferred that auditory information be provided in a female voice, but the remaining eight participants claimed that it did not make a difference whether the voice was male or female. In both display conditions, mean ratings of the severity of symptoms more commonly associated with the use of head-mounted visual displays ranged from 1 ("not noticeable") to 3 on a 7-point scale. One rating that exceeded the midpoint rating of 4 was attributed by the participant who assigned this score to a pre-existing condition.

At the conclusion of testing in both display modes, the participants were queried about their display preference. Six of the 12 participants indicated that all the information presented in this study should be presented visually but two of the six participants qualified their opinion by stating that unit information should be presented auditorily. Three of the 12 participants indicated that all information should be presented auditorily. Similarly, but by contrast, one of these two participants noted that unit information, on the other hand, should be presented visually. The remaining three participants all indicated that navigational information should be presented visually and that target and unit information should be presented auditorily. Table 9 shows a count of the participants' modality preference by information type.

Table 9

Display Modality Preference by Information Type

	Auditory	Visual
Path	3	9
Waypoint	3	9
Target	6	6
Unit	7	5

Many of the participants who preferred the visual condition noted that they thought it "took more time" to navigate in the visual mode because of the need to stop to view the HMD. They noted that, in the auditory mode, they could listen to information while moving. The participants agreed that the visual display was "easier to follow" and "easier to recall." One participant added that the auditory condition "required more memorization."

DISCUSSION

In this study, performance of land navigation and other mission tasks required the participants to maintain an awareness of their position with respect to different objects within their environment. These objects included the designated path, waypoints, targets, and other friendly and enemy units. In both display conditions, information about the position of each object was obtained by depressing a designated button on a keypad that the participant wore on his belt.

The findings of the investigation indicate that there were no statistically significant differences between display conditions in navigation or target acquisition performance or in the frequency at which the participants accessed information about object position. However, the analysis of responses to probe questions revealed that participants maintained a greater awareness of the position of objects when information was presented visually on an HMD than when the same information was presented auditorily in verbal messages.

Differences found between display conditions in position awareness are attributed to a combination of factors that may have affected the participants' ability to retain and accurately recall information. Among these factors are familiarity with the format in which some position information was presented and perhaps to the participants' ability to integrate and group these data into more easily recallable "chunks."

In this study, position information provided in the auditory mode was verbal, while the information provided about position in the visual mode was predominantly spatial. Previous studies of information processing indicate that verbal and spatial information are processed differently (Broadbent, 1971). In a study of cognitive performance using an HMD while walking, Sampson (1993) found that reaction times to tasks were shorter in response to a spatial display than they were in response to either a verbal or numeric display, but no significant differences were found between these displays in the proportion of correct responses.

In the present study, the participants observed that the visual display was "easier to follow" and "easier to recall." According to one participant, auditory display of position information "required more memorization." Research and related literature about memory indicate that information must be rehearsed in order for it to be retained. Even with rehearsal, this information can decay over time (Sanders & McCormick, 1993). The more information that is stored in short-term or working memory, the more rapid this decay, and the lower the probability of correct recall (Van Cott & Warrick, 1972). According to Card, Moran, and Newell (1983), the visual image stored in working memory decays more rapidly than the auditory image store, but the capacity of the visual image store (17 [7~17] letters) is larger than that of the auditory image store (5 [4.4 ~ 6.2] letters). More information can be remembered if it is "chunked" or grouped in some logical or recognizable order. According to Miller (1956), the maximum number of items that can be retained in working memory is 7 ±2 or 5 to 9 items.

In the visual mode, graphical representation of position may have facilitated "chunking" of information about object position. In the auditory mode, position information was presented in series rather than in parallel, and transformation of these data into a mental image of position may have been more difficult.

Figure 13 depicts information about unit position, which was provided in the visual display mode. The text information shown at the right of the display was presented in the same sequence in the auditory display condition. In the visual mode, the map with overlay of unit position, shown to the left of the text, did not provide any additional information, but it did provide an image to which the participant was more accustomed, albeit in paper form. The simple and familiar symbolic representation of friend and foe shown to the left or right of the designated path offered an image that required less processing than the auditory message. In the auditory mode, the participant was required to link individual pieces of information to create this mental picture. In creating this picture, the participant was required to remember what might seem to be a simple convention: "Enemy—Left" meant that the enemy was to the participant's left—not that the participant was to the left of the enemy. The participants agreed that this convention was straightforward and normally followed it without difficulty. However, on occasion during periods of frustration with some aspect of their performance, some participants expressed amazement that they had suddenly forgotten this convention. It is also important to note that in the auditory mode, numerical data about distance and orientation were presented in individual digits, pre-recorded from "zero" to "nine." In this mode, the participant heard "three..two..zero..meters," not "three-hundred and twenty meters". Here, too, it is expected that some additional processing might be required.

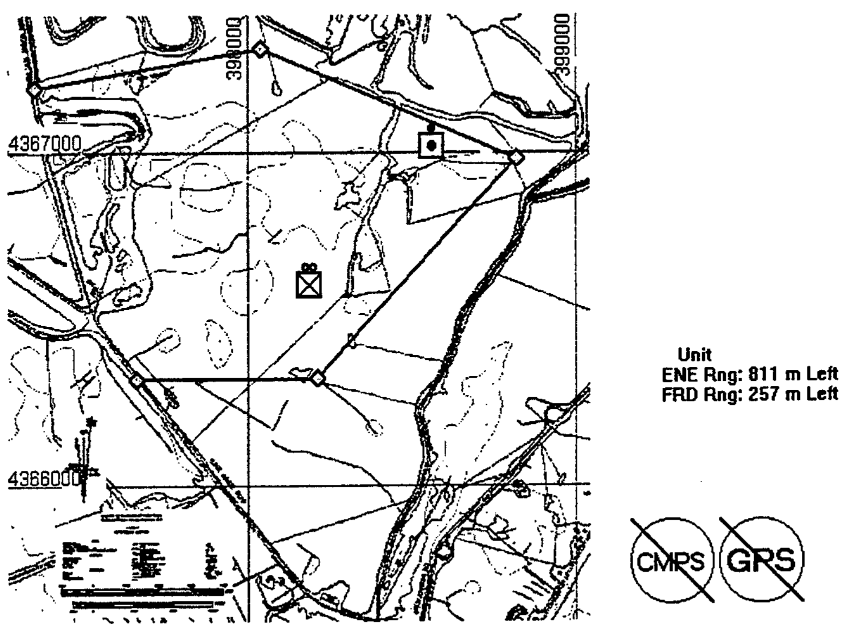


Figure 13. Graphic and alphanumeric information about unit position in the visual display condition.

The assumed increase in cognitive processing requirements in the auditory mode was not reflected by differences between display conditions in ratings of workload as measured by the NASA-TLX. Similarly, no differences were found between display conditions in cognitive performance as measured by the CPASE test battery or in levels of stress as measured by the Salivary Amylase Field Test and stress questionnaires. However, in both display conditions, a significant relationship was found between the participants' ratings of temporal workload and their performance of the logical reasoning task which was a part of the CPASE test battery. The findings indicate that as the participants' perceptions of time demands increased, there was a tendency for their post-test scores on the logical reasoning task to be greater than pre-test scores in the auditory display mode but lower than pre-test scores in the visual display condition. This might suggest that the additional focus required to process information in the auditory condition, and the associated effects of practice, tended to hone the participants' logical reasoning skill, at least temporarily.

Similarly, based on differences between pre- and post-test scores on the spatial rotation task, the design of the visual map display may have presented its own cognitive challenges. In the visual mode, post-test scores on the spatial rotation task were significantly higher than pre-test scores. This finding corresponds with that of a previous study (Glumm et al., 1998) and is attributed to the practice the participants received in mentally rotating the map display that was fixed in the "north-up" direction.

Although participants appeared to maintain a greater awareness of the position of waypoints, targets, and other units in the visual display condition, differences between display modes in navigation and target acquisition performance were not statistically significant. This lack of a difference between displays in the performance of these latter two tasks may reflect the greater frequency at which position information about "path" and "target" was accessed, as well as differences in cognitive processing requirements between these tasks and the task of integrating and recalling information about relative position.

Variability in navigation and target acquisition performance among participants was high on some legs of the path. Such variability may have been influenced by a combination of factors. For example, contrary to expectations, the analysis of the number of targets destroyed indicated that fewer targets were destroyed on Leg 2, which was the mildest leg of the path, than on legs where vegetation was more dense (i.e., Legs 1 and 3). This finding is attributed to one target on Leg 2 that appeared to evade participants in both conditions. A few participants insisted on tracking this target. ("My display tells me I'm right on top of it. It's got to be here somewhere!") Normally, they were correct and their persistence was rewarded. The persistence of a few, however, may have caused a greater variance among participants in time to destroy targets and travel velocity, thus also reducing statistical confidence in differences between display conditions.

Generally, the main effect for path leg found in the analyses of travel velocity and measures of target acquisition performance is attributed to differences among legs in vegetation density. Vegetation on Leg 4 was more dense than on Leg 1 but less dense than on Leg 3. Leg 3 contained greater masses of thorny vegetation than the other three legs of the path, and movement through this segment of the course was slow, if not painful. Leg 2 was the mildest leg of the path, characterized by open woods with tall, well-spaced trees. As might be expected, overall velocities were higher on Leg 2 than on Legs 3 and 4. Leg 3 ran between two marshy areas near which briars thickened and water at times was above the participants' boots. For safety, the participants were advised to adhere as closely as possible to path on this leg so as to avoid more difficult terrain. The greater number of targets destroyed on Leg 3 than on Legs 2 and 4 may reflect the participants' attempts to heed this advice and the greater likelihood of encountering targets in doing so. Nonetheless, time to destroy targets tended to be higher on Leg 3 where the thick vegetation may have reduced the distance from which targets could be seen.

Factors that may have caused differences in performance between path legs may have also influenced relationships between the participants' experience of workload and time to destroy targets. In the auditory mode, as the participants' perceptions of physical workload increased, time to destroy targets also tended to increase. In the visual mode, as time demands increased, time to destroy targets tended to decrease.

Those who participated in this study were well motivated and determined to excel in both display conditions. Neither the research environment nor experimental conditions appeared to have a significant impact on levels of fatigue or stress. In a battlefield environment, however, factors that may have had a minimal effect on performance in this study could induce larger decrements. The findings of this investigation emphasize the need for greater focus on visual and auditory display design for the information-rich battlefield of tomorrow.

CONCLUSIONS AND RECOMMENDATIONS

This study did not show any statistically significant differences between display conditions in navigation time and accuracy or in measures of target acquisition performance as determined by the number of targets destroyed and the time to destroy these targets. No differences were found between the two display modalities in measures of stress, cognitive performance, or ratings of workload. However, the findings did indicate that the military participants maintained a greater awareness of their location with respect to waypoints, targets, and other units when position information was presented visually on an HMD than when this information was presented auditorily in verbal messages. Differences between display conditions in position awareness are attributed to a combination of factors that may have affected the participants' ability to retain and accurately recall information. In the visual mode, graphical representation of position information may have facilitated "chunking." In the auditory mode, position information was presented in series rather than in parallel, and transformation of these data into a mental image of position may have been more difficult.

In the future battlefield, the soldier will have access to greater amounts of information. As the amount and diversity of information increases, so will menu and visual display complexity, along with cognitive processing requirements. The more information the soldier is required to remember, the greater the likelihood of errors in recall. The design of visual and auditory displays and the proper use of these display modalities in presenting information will have a major impact on soldier performance, especially in the presence of fatigue. In an information-rich environment, it is important that the soldier be provided easy access to critical information. Whether this information is provided visually or auditorily, the format in which the information is presented should enable the soldier to easily assimilate and integrate these data into a logical and meaningful picture of the battlefield that can be accurately recalled.

Advancements in three-dimensional visual and auditory display technology offer new opportunities to convey information in a more natural, intuitive form. In enabling the soldier to exploit expanded information resources, researchers must not only recognize the advantages and disadvantages of each sensory display modality but must also accept the symbiotic relationship that exists between them.

Literature about cognitive and perceptual processing is rich with studies concerning mechanisms of processing within both the visual and auditory modality. However, much of the research treats the visual and auditory modalities as being independent of one another. Any legitimate theory of information processing will need to integrate both visual and auditory components of attention and cognition. To truly discern how the visual and auditory systems interact, it will be necessary to develop a better understanding of the brain mechanisms that mediate such processing. Developing a greater understanding of the interaction between auditorily and visually presented information is central to the issue of enhanced cognitive and physical performance in the future battlefield.

REFERENCES

Amburn, P. (1994) Development and evaluation of an air-to-air combat debriefing system using a head-mounted display. (unpublished dissertation). Chapel Hill, NC.

Baddeley, A. (1968). A 3-minute reasoning task based on grammatical transformation. Psychonomic Science, 10, 341-342.

Broadbent, D.E. (1971). Decision and stress. London: Academic Press.

Card, S.K., Moran, T.P., & Newell, A. (1983). The model human processor. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), Handbook of perception and human performance, 45, 1-35. New York: John Wiley and Sons.

Chatterton, R.T., Vogelsong, K.M., Lu, Y.C., Ellman, A.B. & Hudgens, G.A. (1996). Salivary alpha-amylase as a measure of endogenous adrenergic activity. Clinical Physiology, 16(4), 433-448.

Glumm, M.M., Marshak, W.P., Branscome, T.A., Wesler, M.Mc., Patton, D.J., & Mullins, L.L. (1998). A comparison of soldier performance using current land navigation equipment with information integrated on a helmet-mounted display. (ARL-TR-1604). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Green, D.M., & Swets, J.A. (1966). Signal detection theory and psychophysics. New York: John Wiley and Sons.

Hart, S.G., & Staveland, L.E. (1988). Development of the NASA task load index (TLX): Results of empirical and theoretical research. In P.A. Hancock & Meshkati (Eds.), Human mental workload (pp. 139-183). Amsterdam: North Holland.

Marshak, W.P., Kuperman, G., Ramsey, E., & Wilson, D. (1987). Situation awareness in map displays, Proceedings of the Human Factors Society 31st Annual Meeting, 1, 533-535.

McKinley, R.L., & Ericson, M.A. (1995). Flight demonstration of a 3-D auditory display. In R.H. Gilkey & T.R. Anderson (Eds.), Binaural and spatial hearing in real and virtual environments (pp. 683-700). Mahawah, NJ: Lawrence Erlbaum Associates.

McKinley, R., Ericson, M., & D'Angelo, W. (1994). Three-Dimensional auditory displays: Development, applications and performance. Aviation, Space, and Environmental Medicine, 5, A31-A38.

McKinley, R., D'Angelo, W.R., Haas, M.W., Perrot, D.R., Nelson, W.T., Hettinger, L.J., & Brickman, B.J. (1995). An initial study of the effects of 3-dimensional auditory cueing of visual target detection. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting, 1, 119-124.

Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, 81-97.

Mullins, L.L. (in progress). Cognitive performance assessment for stress endurance (CPASE). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Myers, A., & Hansen, C.H. (1980). Experimental psychology (3rd ed.). Belmont, CA: Wadsworth, Inc.

Occupational Safety and Health Administration (March 8, 1983). Occupational noise exposure; hearing conservation amendment; final rules. OSHA-1983. Federal Register, 48:46, 9776. Washington DC: Superintendent of Documents.

Riggs, L.A., Vision. In J.W. Kling, & L.A. Riggs (Eds) (1971). Woodworth and Schlosberg's experimental psychology (3rd edition). New York: Holt, Rinehart, and Winston.

Sampson, J.B. (1993). Cognitive performance of individuals using a head-mounted display while walking. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, 1, 338-342.

Sanders, M.S., & McCormick, E.J. (1993). Human factors in engineering design. New York: McGraw-Hill, Inc.

U.S. Army (1991). Hearing conservation (U.S. Army Pamphlet 40-501). Washington, DC: Headquarters, Department of the Army.

Van Cott, H.P., & Warrick, M.J. (1972). Man as a system component. In H.P. Van Cott & R.G. Kinkade (Eds.), Human engineering guide to equipment design (Rev. ed.). Washington, DC: Government Printing Office.

APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

Subject No.: ________

DEMOGRAPHIC QUESTIONNAIRE

Please answer the following questions. The information you provide will be kept CONFIDENTIAL.

1. Name: ____
   Last First Middle Initial

2. Age: __________

3. Rank: ________________

4. Military Occupational Specialty (MOS): ______________

5. Time in Service: ______years ________ months

6. Time in grade: _______years ________ months

7. Time in MOS: _______years ________ months

8. Are you left- or right-handed?

   Left-Handed [ ] Right-Handed [ ]

9. Which eye do you normally use to aim your weapon?

   Left Eye [ ] Right Eye [ ]

10. Do you wear eyeglasses or contacts?

    Yes [ ] No [ ]

11. Have you ever worn a head- or helmet-mounted display (HMD)?

    Yes [ ] No [ ]

12. Generally, how would you rate your land navigation skills?

    Excellent [ ]
    Good [ ]
    Neither Good nor Bad [ ]
    Fair [ ]
    Poor [ ]

APPENDIX B

SALIVARY AMYLASE FIELD TEST AND STRESS QUESTIONNAIRES

SALIVARY AMYLASE FIELD TEST AND STRESS QUESTIONNAIRES

Salivary Amylase Field Test

Amylase is an enzyme that hydrolyzes starch to oligosaccharides and then slowly to maltose and glucose. Measurement of amylase in saliva involves chemical color changes according to standard photometric procedures developed by Northwestern University (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996). This method combines time lapse and temperature data to derive a quantifiable level of stress.

A saliva sample is obtained from a subject using a small, clean rectangular sponge (1 in. x .5 in. x .5 in). The sponge is contained in a pre-labeled plastic cup with lid. The subject is instructed to remove the sponge from the cup and roll the sponge in his or her mouth for 1 minute. The subject is then asked to place the sponge back in the cup, close the lid, and hand the cup to the monitor. The cup containing the sponge is then placed in an insulated bag with an ice pack or refrigerated, as needed, to keep the sample cold for later assay.

References:

Chatterton, R.T., Vogelsong, K.M., Lu, Y., Ellman, A.B. & Hudgens, G.A. (1996). Salivary amylase as a measure of endogenous adrenergic activity. Clinical Psychology, 16.

Stress Questionnaires

A select battery of state questionnaires used in previous ARL research investigations were administered to the study participants (Fatkin, King, & Hudgens, 1990; Hudgens, Malkin, & Fatkin, 1992; Blewett, O'Hern, Harris, Redmond, Fatkin, Rice, & Popp, 1994; Fatkin & Hudgens, 1994; Fatkin, Treadwell, Knapik, Patton, Mullins, & Swann, 1997). This battery has been proven sensitive to the degree of stress experienced in a variety of situations and includes standardized measures that have demonstrated construct validity within the stress research literature. A description of the questionnaires in this battery and their administration in the present study follow.

The Self-Efficacy Scale (SES) was administered before each test run in each condition. This scale asks respondents to rate their level of confidence on a scale of 1-10 in their ability to do well with reference to anticipation of "today's experiences." Positive correlations have been obtained between self-efficacy and vocational, educational and military success (Sherer et al, 1982; Bandura, 1977; Hudgens, Malto, Geddie, & Fatkin, 1991).

The following measures were obtained before and immediately after a test run in each display condition:

Multiple Affect Adjective Check List -Revised (MAACL-R) . Because of the improved discriminant validity and the control of the checking response set, the MAACL-R with its five subscales -- anxiety, depression, hostility, positive affect and negative affect -- has been particularly suitable for investigations that postulate changes in specific affects in response to stressful situations. The participants were instructed to answer according to how they feel "right now" or how they felt during a specific time period or event (Zuckerman & Lubin, 1985).

The Subjective Stress Scale (SUBJ) was developed to detect significant affective changes in stressful conditions. The participants are instructed to select one word from a list of 15 adjectives that describe how they feel "right now" or how they felt during a specific time period or event (Kerle and Bialek, 1958).

The Specific Rating of Events Scale (SRE) is a measure designed for the ARL stress program in which the participants rate (on a scale of 0 for "not at all stressful" to 100 for "most stress possible") how stressed they feel "right now" or how stressful an event or time period was to them (Fatkin, King, & Hudgens, 1990).

References:

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, 191-215.

Blewett, W.K., O'Hern, M., Harris, L., Redmond, D.P., Fatkin, L.F., Rice, D.J., & Popp, K. (1994). A P2NBC2 report: Patient decontamination at mobile medical facilities (ERDEC-TR-255). Aberdeen Proving Ground, MD: Edgewood Research, Development and Engineering Center.

Fatkin, L.T., & Hudgens, G.A. (1994). Stress perceptions of soldiers participating in training at the Chemical Defense Training Facility: The mediating effects of motivation, experience, and confidence level (ARL-TR-365). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Fatkin, L.T., King, J.M., & Hudgens, G.A. (1990). Evaluation of stress experienced by Yellowstone Army fire fighters (ARL-TM 9-90). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Hudgens, G.A., Malto, B.O., Geddie, J.C., & Fatkin, L.T. (1991). Stress evaluation for the TOW Accuracy Study (TN No. 5-91). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Kerle, R. H., & Bialek, H. M. (1958). The construction, validation, and application of a Subjective Stress Scale (Staff Memorandum Fighter IV, Study 23). Presidio of Monterey, CA: US Army Leadership Human Research Unit.

Sherer, M., Maddux, J.E., Mercandante, B., Prentice-Dunn, S., Jacobs, B., & Rogers, R.W. (1982). The Self-Efficacy Scale: Construction and validation. Psychological Reports, 51, 663-671.

Zuckerman, M., & Lubin, B. (1985). Manual for the Multiple Affect Adjective Check List-Revised. San Diego, CA: Educational and Industrial Testing Service.

LIFE EVENTS FORM I

1. Check the appropriate response: "I have recently experienced:"

    Unusually low stress ______
    Mild stress ______
    Moderate stress ______
    High stress ______
    Unusually high stress ______

2. Have you recently experienced any events having an impact on your life? Yes ____ No ____
    Please list them and indicate them as positive or negative by placing them in the corresponding column:

    POSITIVE — DATE EVENT OCCURRED

    NEGATIVE — DATE EVENT OCCURRED

3. How would you rate the way you handled any events that occured?

    Very well ______
    Well ______
    Adequate ______
    Poorly ______
    Very Poorly ______

4. "Considering all that has happened recently, my resources for responding to the events were:"

    More than adequate ______
    Adequate ______
    Less than adequate ______

MAACL-R

DIRECTIONS: On the following sheet mark an X in the boxes beside the words which describe how you feel right now. Some of the words may sound alike, but we want you to check all the words that describe your feelings.

A D H

PA SS

1 ☐ active
2 ☐ adventurous
3 ☐ affectionate
4 ☐ afraid
5 ☐ agitated
6 ☐ agreeable
7 ☐ aggressive
8 ☐ alive
9 ☐ alone
10 ☐ amiable
11 ☐ amused
12 ☐ angry
13 ☐ annoyed
14 ☐ awful
15 ☐ bashful
16 ☐ bitter
17 ☐ blue
18 ☐ bored
19 ☐ calm
20 ☐ cautious
21 ☐ cheerful
22 ☐ clean
23 ☐ complaining
24 ☐ contented
25 ☐ contrary
26 ☐ cool
27 ☐ cooperative
28 ☐ critical
29 ☐ cross
30 ☐ cruel
31 ☐ daring
32 ☐ desperate
33 ☐ destroyed
34 ☐ devoted
35 ☐ disagreeable
36 ☐ discontented
37 ☐ discouraged
38 ☐ disgusted
39 ☐ displeased
40 ☐ energetic
41 ☐ enraged
42 ☐ enthusiastic
43 ☐ fearful
44 ☐ fine
45 ☐ fit
46 ☐ forlorn
47 ☐ frank
48 ☐ free
49 ☐ friendly
50 ☐ frightened
51 ☐ furious
52 ☐ lively
53 ☐ gentle
54 ☐ glad
55 ☐ gloomy
56 ☐ good
57 ☐ good-natured
58 ☐ grim
59 ☐ happy
60 ☐ healthy
61 ☐ hopeless
62 ☐ hostile
63 ☐ impatient
64 ☐ incensed
65 ☐ indignant
66 ☐ inspired
67 ☐ interested
68 ☐ irritated
69 ☐ jealous
70 ☐ joyful
71 ☐ kindly
72 ☐ lonely
73 ☐ lost
74 ☐ loving
75 ☐ low
76 ☐ lucky
77 ☐ mad
78 ☐ mean
79 ☐ meek
80 ☐ merry
81 ☐ mild
82 ☐ miserable
83 ☐ nervous
84 ☐ obliging
85 ☐ offended
86 ☐ outraged
87 ☐ panicky
88 ☐ patient
89 ☐ peaceful
90 ☐ pleased
91 ☐ pleasant
92 ☐ polite
93 ☐ powerful
94 ☐ quiet
95 ☐ reckless
96 ☐ rejected
97 ☐ rough
98 ☐ sad
99 ☐ safe
100 ☐ satisfied
101 ☐ secure
102 ☐ shaky
103 ☐ shy
104 ☐ soothed
105 ☐ steady
106 ☐ stubborn
107 ☐ stormy
108 ☐ strong
109 ☐ suffering
110 ☐ sullen
111 ☐ sunk
112 ☐ sympathetic
113 ☐ tame
114 ☐ tender
115 ☐ tense
116 ☐ terrible
117 ☐ terrified
118 ☐ thoughtful
119 ☐ timid
120 ☐ tormented
121 ☐ understanding
122 ☐ unhappy
123 ☐ unsociable
124 ☐ upset
125 ☐ vexed
126 ☐ warm
127 ☐ whole
128 ☐ wild
129 ☐ willful
130 ☐ wilted
131 ☐ worrying
132 ☐ young

SUBJECTIVE SCALE

Circle one word that best describes how you feel right now.

Wonderful

Fine

Comfortable

Steady

Not Bothered

Indifferent

Timid

Unsteady

Nervous

Worried

Unsafe

Frightened

Terrible

In Agony

Scared Stiff

RATING OF EVENTS - SPECIFIC

1. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (✓) to rate how much stress you are experiencing <u>right</u> <u>now</u>.

Not at All Stressful	Most Stress Possible

0 10 20 30 40 50 60 70 80 90 100

2. At what number value does the check mark touch the line? ________

SSE

1. On a scale from 1 to 10, how confident are you in your ability to deal with today's experiences? Please circle one of the numbers below.

1	2	3	4	5	6	7	8	9	10
Not at all confident									Extremely confident

APPENDIX C

COGNITIVE PERFORMANCE ASSESSMENT FOR STRESS AND ENDURANCE (CPASE)

COGNITIVE PERFORMANCE ASSESSMENT FOR STRESS AND ENDURANCE (CPASE)

CPASE (Mullins, 1996) is administered in a paper and pencil format, and emphasizes speed and accuracy in completion of the following test measures:

Verbal Memory. The short-term memory test uses lists taken from a word usage text (Thorndike & Lorge, 1944). Each list consists of twelve one- or two-syllable words with the most common usage rating (100 or more per million). Soldiers are given one minute to study the list and one minute for recall.

Logical Reasoning. The reasoning test evaluates an understanding of grammatical transformations on sentences of various levels of syntactic complexity (Baddeley, 1968). Each item consists of a true or false statement such as "A follows B----AB" (false) or "B precedes A----BA" (true). The test is balanced for the following conditions: positive versus negative, active versus passive, precedes versus follows, order of statement letter presentation, and order of letters in the pair (equivalent to balancing for true or false condition). Letter pairs are selected to minimize acoustic and verbal confusion. One minute is given to complete the 32 evaluations.

Addition. This task, adapted from Williams and Lubin (1967), tests working memory. Each calculation consists of a pair of three-digit numbers which are selected from a random number table. The task is subject-paced. Soldiers have 30 seconds to complete as many of the 15 problems as possible.

Spatial Rotation. Spatial ability is tested using a mental rotation task adapted from Shepherd's work (1978). A six-by-six grid is enclosed within a hexagon measuring 2.8 centimeters across the diameter. Portions of the grid are blackened to create random patterns. To the right of each test pattern are three similar patterns. One of the three patterns is identical to the test pattern except that it has been rotated. The task is to select this pattern. Each test consists of eighteen items balanced for the number of grids blackened (7, 9, or 11), pattern density (adjacent blocks blackened versus a break between blocks), and rotation of the correct answer (90, 180, or 270 degrees). Two minutes are given to complete the 18 evaluations.

References:

Baddeley, A. (1968). A 3-min reasoning task based on grammatical transformation. Psychonomic Science, 10, 341-342.

Mullins, L. L. (1996). Cognitive performance assessment for stress endurance (CPASE). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Shepard, R.N. (1978). The mental image. American Psychologist, 33, 125-137.

Thorndike, E.L. & Lorge, I. (1944). The teacher's work book of 30,000 words. New York: Columbia University.

Williams, H. L. & Lubin, A. (1967). Speeded addition and sleep loss. Journal of Experimental Psychology, 73 (2), 313-317.

WORD RECALL TASK

INSTRUCTIONS: You will receive a page with of a list of twelve words. Keep this list face down until you are instructed to start the test. Read through the list and write each word in the recopy column as quickly as possible. You will have one minute to write and study the words. You will be asked to recall these words later in the session.

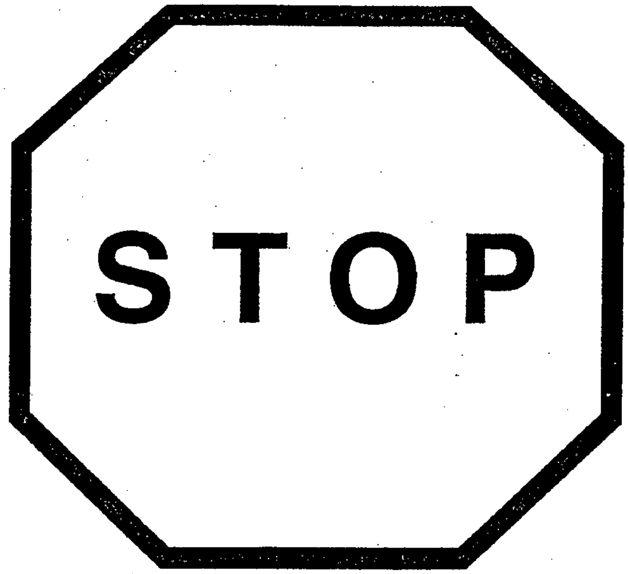
Do not turn to the next page until instructed to do so.

Word List	Recopy
law	______________________
free	______________________
flower	______________________
going	______________________
happy	______________________
sweet	______________________
friend	______________________
window	______________________
man	______________________
fresh	______________________
spring	______________________
paper	______________________

List 1

Word Recall Task

List 1



DO NOT TURN THE PAGE

UNTIL INSTRUCTED

LOGICAL REASONING
INSTRUCTIONS

In the following test there are a number of short sentences each followed by a pair of letters. The sentences claim to describe the order of the two letters. Your task is to read each sentence and to decide whether it is a true or false description of the letter pair which follows it. If you think the sentence describes the letter pair correctly circle True. If you think the sentence does not describe the letter pair correctly then circle False.

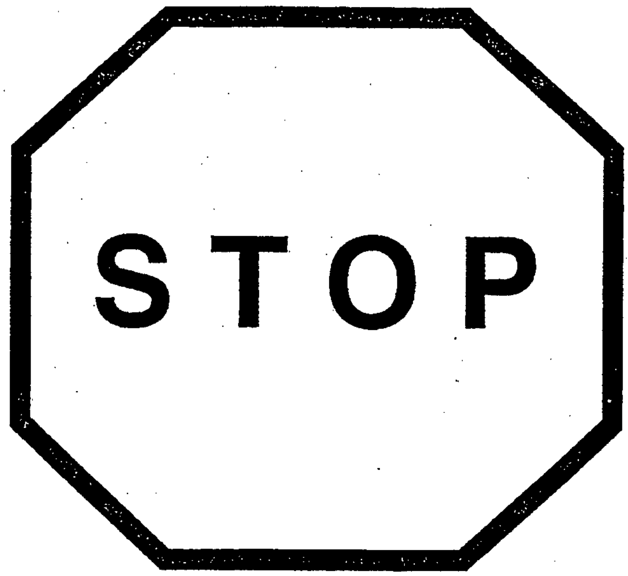
EXAMPLES

1.	A follows B	AB	True False
2.	B precedes A	BA	True False
3.	A is followed by B	BA	True False
4.	B is not followed by A	AB	True False
5.	B is preceded by A	AB	True False

When you start the main test, work as quickly as you can without making mistakes. Start with sentence 1 and work systematically through the test without skipping any items. You will have one minute to complete as many of the statements as possible.

1AB

1.	A does not follow B	AB	True	False
2.	A does not precede B	BA	True	False
3.	B does not follow A	BA	True	False
4.	A precedes B	AB	True	False
5.	A is not preceded by B	BA	True	False
6.	B is not preceded by A	BA	True	False
7.	B precedes A	BA	True	False
8.	B is not followed by A	BA	True	False
9.	B does not follow A	AB	True	False
10.	B is not preceded by A	AB	True	False
11.	B is not followed by A	AB	True	False
12.	A precedes B	BA	True	False
13.	A is not followed by B	AB	True	False
14.	A follows B	BA	True	False
15.	B is preceded by A	BA	True	False
16.	A follows B	AB	True	False
17.	A does not follow B	BA	True	False
18.	A is preceded by B	BA	True	False
19.	B does not precede A	AB	True	False
20.	B follows A	BA	True	False
21.	A is followed by B	AB	True	False
22.	A is preceded by B	AB	True	False
23.	A is followed by B	BA	True	False
24.	B does not precede A	BA	True	False
25.	A is not preceded by B	AB	True	False
26.	A does not precede B	AB	True	False
27.	B is followed by A	BA	True	False
28.	B precedes A	AB	True	False
29.	B is followed by A	AB	True	False
30.	B is preceded by A	AB	True	False
31.	A is not followed by B	BA	True	False
32.	B follows A	AB	True	False



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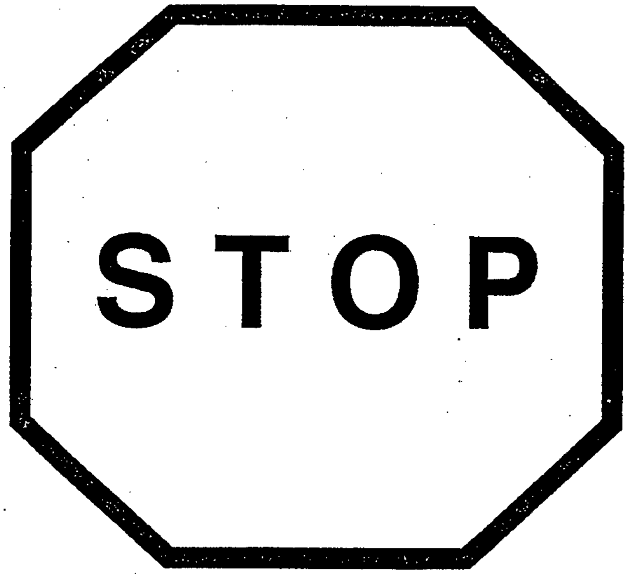
UNTIL INSTRUCTED

Add the Following Numbers Together

104	289	486
223	635	541
241	429	326
421	365	293
792	119	248
956	185	815
789	368	296
523	111	742
698	521	472
743	705	851

1



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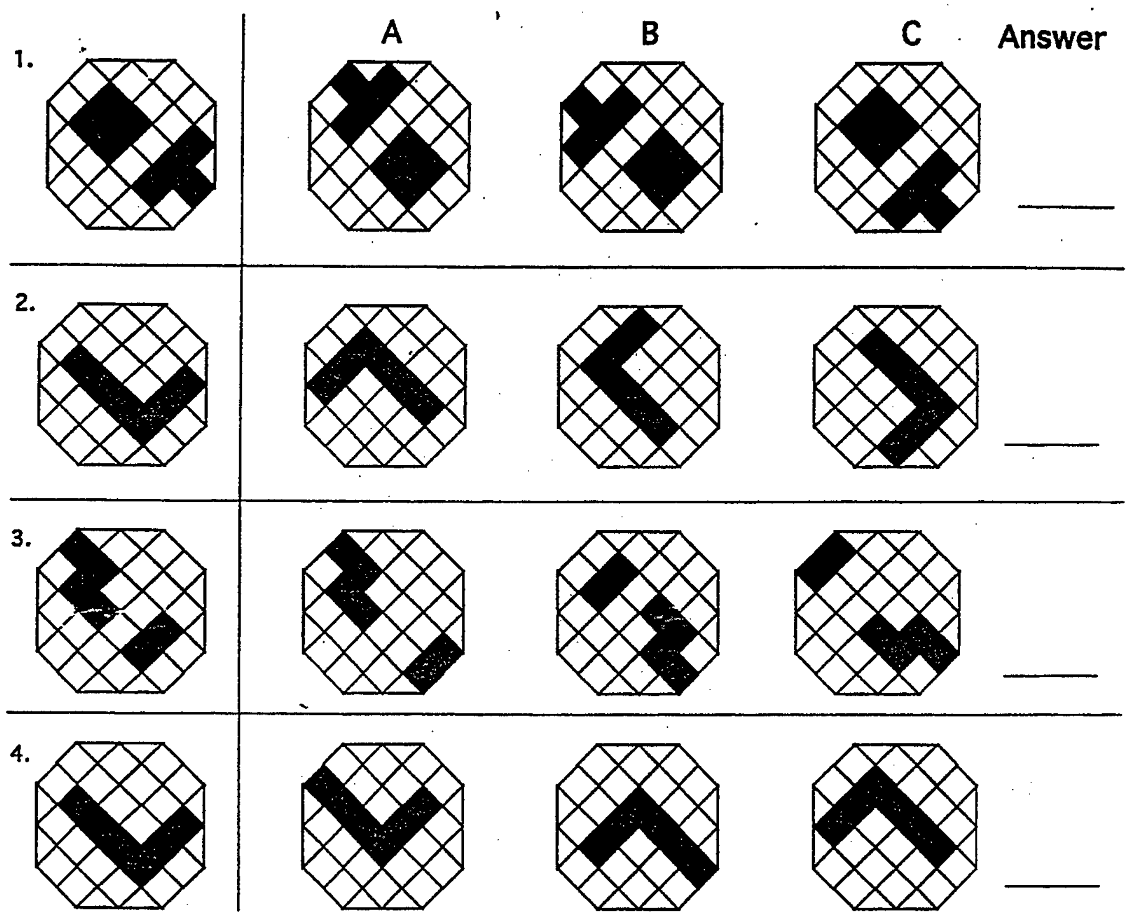
UNTIL INSTRUCTED

Spatial Rotation Task

Instructions: This task consists of rotated patterns. To the right of each pattern there are three similar patterns. One of the three patterns on the right is identical to the pattern to the left except it has been rotated clockwise by 90, 180, or 270 degrees. Pick the pattern that is like the one on the left and write the answer (A, B, or C) to the right in the space provided. Work through the problems in the order they are presented. Do Not Skip Items.

Be careful not to select an item that is a mirror image, or that has been shifted within the frame.

Examples:

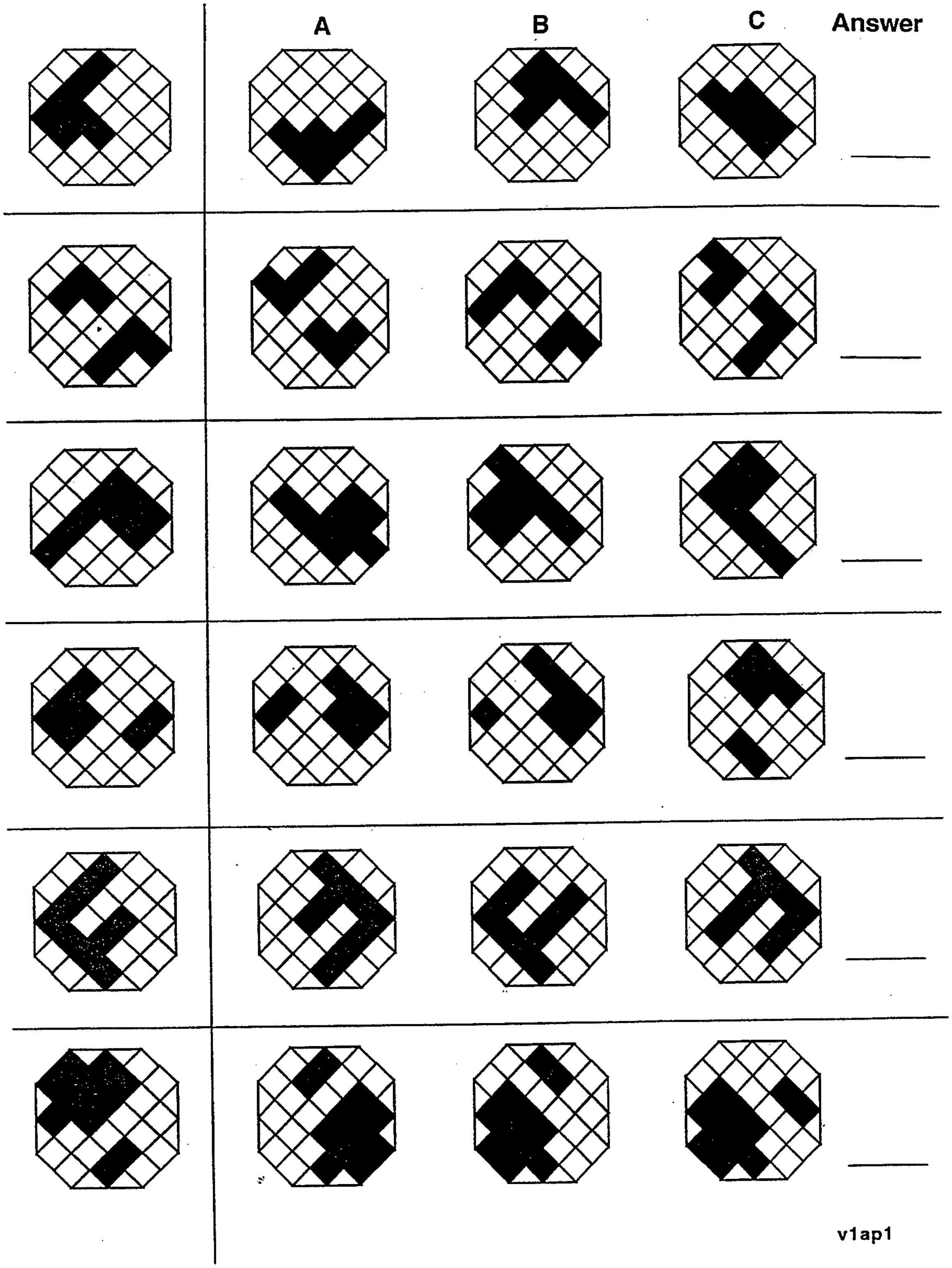


Example 1: The correct answer is B. A and C are incorrect because they are mirror images of the original item.

Example 2: The correct answer is A. Again B and C are mirror images of the original item.

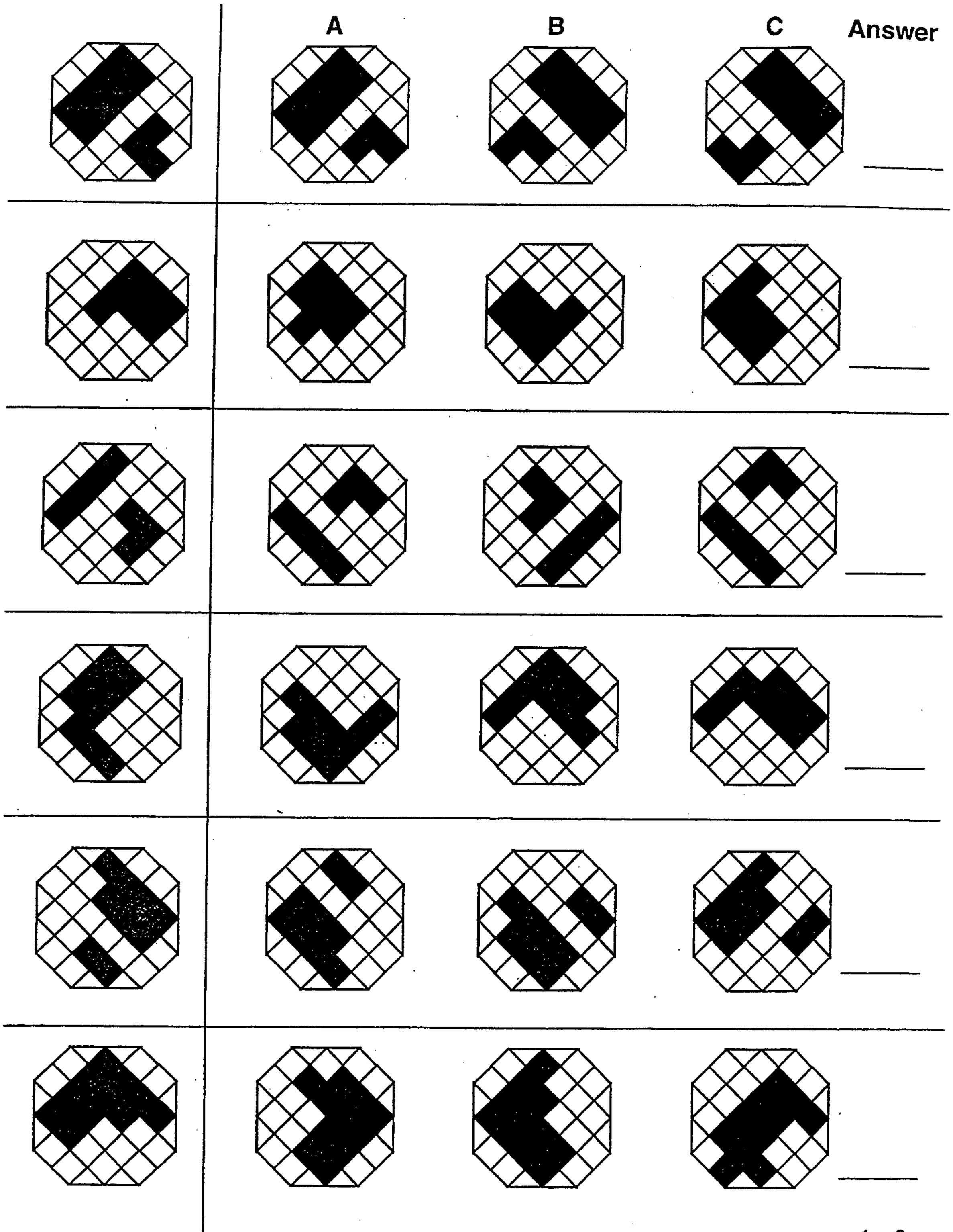
Example 3: The correct answer is B. Note that A and C are incorrect because the 2 block section is shifted to the outer edge of the frame.

Example 4: The correct answer is C. A and B are incorrect because the shape is shifted within the frame.

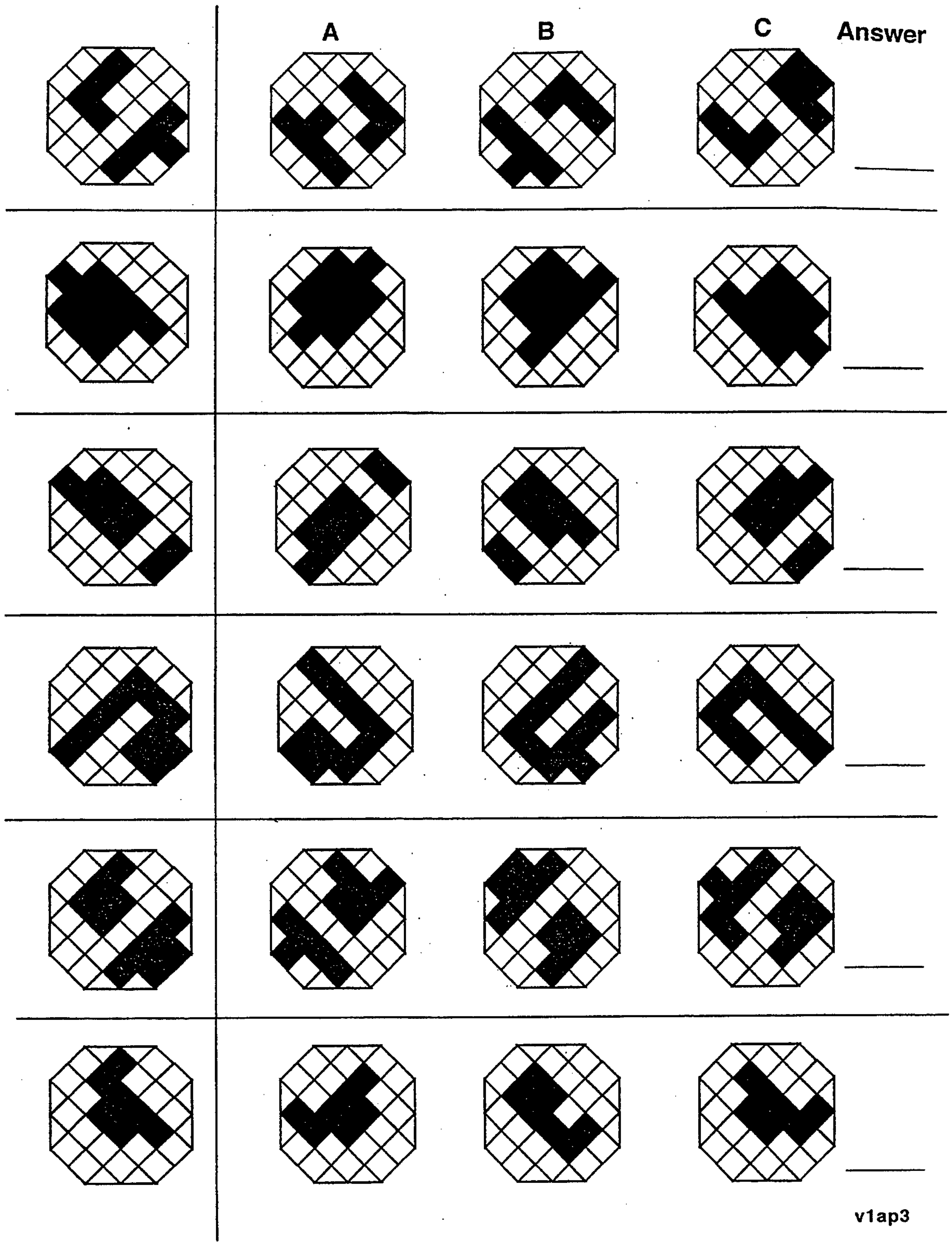


v1ap1

A B C Answer



v1ap2


A
B
C
Answer
v1ap3

APPENDIX D

NASA-TASK LOAD INDEX

7. SUBJECT INSTRUCTIONS: SOURCES-OF-WORKLOAD EVALUATION

Throughout this experiment the rating scales are used to assess your experiences in the different task conditions. Scales of this sort are extremely useful, but their utility suffers from the tendency people have to interpret them in individual ways. For example, some people feel that mental or temporal demands are the essential aspects of workload regardless of the effort they expended on a given task or the level of performance they achieved. Others feel that if they performed well the workload must have been low and if they performed badly it must have been high. Yet others feel that effort or feelings of frustration are the most important factors in workload; and so on. The results of previous studies have already found every conceivable pattern of values. In addition, the factors that create levels of workload differ depending on the task. For example, some tasks might be difficult because they must be completed very quickly. Others may seem easy or hard because of the intensity of mental or physical effort required. Yet others feel difficult because they cannot be performed well, no matter how much effort is expended.

The evaluation you are about to perform is a technique that has been developed by NASA to assess the relative importance of six factors in determining how much workload you experienced. The procedure is simple: You will be presented with a series of pairs of rating scale titles (for example, Effort vs. Mental Demands) and asked to choose which of the items was more important to your experience of workload in the task(s) that you just performed. Each pair of scale titles will appear on a separate card.

Circle the Scale Title that represents the more important contributor to workload for the specific task(s) you performed in this experiment.

After you have finished the entire series we will be able to use the pattern of your choices to create a weighted combination of the ratings from that task into a summary workload score. Please consider your choices carefully and make them consistent with how you used the rating scales during the particular task you were asked to evaluate. Don't think that there is any *correct* pattern; we are only interested in your opinions.

If you have any questions, please ask them now. Otherwise, start whenever you are ready. Thank you for your participation.

Appendix A.

RATING SCALE DEFINITIONS

Title	Endpoints	Descriptions
MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*Low/High*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	*Low/High*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	*Perfect/Failure*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	*Low/High*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	*Low/High*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Appendix B.

Sources-of-Workload Comparison Cards

Effort or Performance	Temporal Demand or Frustration
Temporal Demand or Effort	Physical Demand or Frustration
Performance or Frustration	Physical Demand or Temporal Demand
Physical Demand or Performance 15	Temporal Demand or Mental Demand

Frustration or Effort	Performance or Mental Demand
Performance or Temporal Demand	Mental Demand or Effort
Mental Demand or Physical Demand	Effort or Physical Demand
Frustration or Mental Demand	

16

Appendix C.

Subject ID: ______________ Task ID: ______________

RATING SHEET

MENTAL DEMAND

Low — High

PHYSICAL DEMAND

Low — High

TEMPORAL DEMAND

Low — High

PERFORMANCE

Good — Poor

EFFORT

Low — High

FRUSTRATION

Low — High

17

Appendix D.

Subject ID: ____________ Date: ____________

SOURCES-OF-WORKLOAD TALLY SHEET

Scale Title	Tally	Weight
MENTAL DEMAND		
PHYSICAL DEMAND		
TEMPORAL DEMAND		
PERFORMANCE		
EFFORT		
FRUSTRATION		

Total count = ____________

(NOTE - The total count is included as a check. If the total count is not equal to 15, then something has been miscounted. Also, no weight can have a value greater than 5.)

Appendix E.

Subject ID: ____________ Task ID: ____________

WEIGHTED RATING WORKSHEET

Scale Title	Weight	Raw Rating	Adjusted Rating (Weight X Raw)
MENTAL DEMAND			
PHYSICAL DEMAND			
TEMPORAL DEMAND			
PERFORMANCE			
EFFORT			
FRUSTRATION			

Sum of "Adjusted Rating" Column = ________

WEIGHTED RATING =
[i.e., (Sum of Adjusted Ratings)/15]

APPENDIX E

POST-TEST QUESTIONNAIRES

POST-RUN QUESTIONNAIRE

Please answer each of the following questions. Your comments are appreciated and can be provided in the space available or on the reverse side of this sheet.

1. Did you have any difficulty hearing or understanding the ***auditory*** information?

No [ ]
Yes [ ] if so, please explain: ____________________

____

2. How easy or difficult was it to perform each of the following tasks using position information provided **auditorily**?

	Very Easy	Easy	Neither Easy nor Difficult	Difficult	Very Difficult
(a) Determine your lateral location and azimuth orientation with respect to the path?	[ ]	[ ]	[ ]	[ ]	[ ]
(b) Determine your position with respect to the waypoint to which you were traveling?	[ ]	[ ]	[ ]	[ ]	[ ]
(c) Determine your position with respect to enemy and friendly units?	[ ]	[ ]	[ ]	[ ]	[ ]
(d) Determine your position with respect to targets?	[ ]	[ ]	[ ]	[ ]	[ ]

Comment: ____________________

____

3. On the average, how often did you request each of the following information?

	Every 25 m	50 m	100 m	200 m	Other (Please specify)
(a) Path	[ ]	[ ]	[ ]	[ ]	[ ] ________
(b) Waypoint	[ ]	[ ]	[ ]	[ ]	[ ] ________
(c) Target	[ ]	[ ]	[ ]	[ ]	[ ] ________
(d) Unit	[ ]	[ ]	[ ]	[ ]	[ ] ________

Comment: ____

4. How often did you have to stop to listen to the requested information?

All the time	[ ]
Often	[ ]
Sometimes	[ ]
Rarely	[ ]
Never	[ ]

Comment: ____

5. In what gender voice would you prefer to hear each of the following types of position information?

	Male	Female	Makes No Difference
(a) Path	[ ]	[ ]	[ ]
(b) Waypoint	[ ]	[ ]	[ ]
(c) Target	[ ]	[ ]	[ ]
(d) Unit	[ ]	[ ]	[ ]

Comment: ____________________

6. Would you like to hear position information that sounds like its coming from that location? (Check one)

No [ ] Yes [ ]

Comment: ____________________

7. Please rate the severity of each symptom you may be experiencing now or experienced during your mission?

Blurred vision	1 (not noticeable)	2	3	4	5	6	7 (severe)
Headache	1 (not noticeable)	2	3	4	5	6	7 (severe)
Eye strain	1 (not noticeable)	2	3	4	5	6	7 (severe)
Tight neck muscles	1 (not noticeable)	2	3	4	5	6	7 (severe)
Stiff whole body	1 (not noticeable)	2	3	4	5	6	7 (severe)
Other *(Please specify)* ________	1 (not noticeable)	2	3	4	5	6	7 (severe)

Comment: ____________________

POST-RUN QUESTIONNAIRE

Please answer each of the following questions. Your comments are appreciated and can be provided in the space available or on the reverse side of this sheet.

1. Did you have any difficulty seeing or understanding the ***visual*** information?

No [ ]
Yes [ ] if so, please explain: ______________________________

____

2. How easy or difficult was it to perform each of the following tasks using position information provided **visually**?

	Very Easy	Easy	Neither Easy nor Difficult	Difficult	Very Difficult
(a) Determine your lateral location and azimuth orientation with respect to the path?	[ ]	[ ]	[ ]	[ ]	[ ]
(b) Determine your position with respect to the waypoint to which you were traveling?	[ ]	[ ]	[ ]	[ ]	[ ]
(c) Determine your position with respect to enemy and friendly units?	[ ]	[ ]	[ ]	[ ]	[ ]
(d) Determine your position with respect to targets?	[ ]	[ ]	[ ]	[ ]	[ ]

Comment: ______________________________

____

3. On the average, how often did you request each of the following information?

Every	25 m	50 m	100 m	200 m	Other (Please specify)
(a) Path	[ ]	[ ]	[ ]	[ ]	[ ] ________
(b) Waypoint	[ ]	[ ]	[ ]	[ ]	[ ] ________
(c) Target	[ ]	[ ]	[ ]	[ ]	[ ] ________
(d) Unit	[ ]	[ ]	[ ]	[ ]	[ ] ________

Comment: ____

____

4. How often did you have to stop to view the requested information on the HMD?

All the time [ ]
Often [ ]
Sometimes [ ]
Rarely [ ]
Never [ ]

Comment: ____

____

5. Please rate the severity of each symptom you may be experiencing now or experienced during your mission?

Blurred vision	1 (not noticeable)	2	3	4	5	6	7 (severe)
Headache	1 (not noticeable)	2	3	4	5	6	7 (severe)
Eye strain	1 (not noticeable)	2	3	4	5	6	7 (severe)
Tight neck muscles	1 (not noticeable)	2	3	4	5	6	7 (severe)
Stiff whole body	1 (not noticeable)	2	3	4	5	6	7 (severe)
Other *(Please specify)* ________	1 (not noticeable)	2	3	4	5	6	7 (severe)

Comment: ____

____

POST-TEST QUESTIONNAIRE

Please answer each of the following questions. Your comments are appreciated and can be provided in the space available or on the reverse side of this sheet.

1. In what form would you prefer to receive the following position information (Check *one* for each type of information).

	Visually	Auditorily	Makes No Difference
(a) Path	[ ]	[ ]	[ ]
(b) Waypoint	[ ]	[ ]	[ ]
(c) Unit	[ ]	[ ]	[ ]
(d) Target	[ ]	[ ]	[ ]

Comment: ______________________________

____

2. Are there other types of information that you would like to receive auditorily? or visually? to perform the tasks that you performed in this study?

(a) **Other Auditory?**
No [ ]
Yes [ ] if so, please list: ______________

(b) **Other Visual?**
No [ ]
Yes [ ] if so, please list: ______________

Comment: ______________________________

____

3. Do you have any suggestions for improving the visual or auditory displays? ______________________________

____

____

APPENDIX F

PERFORMANCE DATA

LEG	DISTANCE TRAVELED			
	Auditory		Visual	
	Mean	SD	Mean	SD
1	2.27	1.21	2.01	.80
2	1.87	.42	1.97	.46
3	1.85	.68	1.80	.46
4	1.71	.52	2.09	.49
Overall	1.93	.13*	1.98	.12*

LEG	TRAVEL VELOCITY			
	Auditory		Visual	
	Mean	SD	Mean	SD
1	53.73	21.66	52.84	14.73
2	52.09	9.32	64.24	19.43
3	47.10	18.07	49.24	11.94
4	41.96	9.77	48.98	9.17
Overall	48.72	2.77*	53.83	3.24*

LEG	NUMBER OF TARGETS DESTROYED			
	Auditory		Visual	
	Mean	SD	Mean	SD
1	4.50	.52	4.58	.79
2	3.58	1.31	4.33	.98
3	4.83	.39	4.83	.39
4	4.08	.90	4.08	1.00
Overall	4.25	.12*	4.46	.18*

LEG	TIME TO DESTROY TARGETS			
	Auditory		Visual	
	Mean	SD	Mean	SD
1	75.83	27.37	72.74	21.03
2	67.34	36.08	96.53	86.16
3	135.38	99.65	109.90	67.13
4	83.67	36.77	120.70	35.73
Overall	90.56	6.80*	99.97	9.49*

* Satndard Error.

LEG	INFORMATION ACCESS															
	Auditory								Visual							
	Path		Waypoint		Target		Unit		Path		Waypoint		Target		Unit	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
1	69.08	85.52*	11.67	6.61*	13.33	5.37*	2.83	2.29*	37.00*	13.45	9.17	9.82*	15.67	7.72*	3.83	3.64*
2	73.25	39.42*	14.92	13.67*	19.08	7.09*	3.42	2.50*	53.50*	16.27	10.50	9.69*	22.58	9.82*	5.67	4.08*
3	54.42	25.00*	12.92	11.05*	17.50	10.77*	4.08	1.68*	50.75*	20.54	11.17	11.37*	20.67	5.90*	4.67	2.90*
4	61.08	35.76*	9.50	5.68*	17.67	11.67*	3.83	2.04*	52.50*	22.45	15.92	18.58*	24.08	8.40*	5.25	3.36*
Overall	253.83	47.15*	47.42	10.52*	71.58	8.18*	13.42	2.28*	199.58	19.29*	49.25	14.04*	87.75	8.17*	20.00	3.70*

* Satndard Error.

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13. ABSTRACT *(Maximum 200 words)*

This report describes a field study designed to measure the effects of an auditory versus a visual presentation of position information on soldier performance of land navigation and target acquisition tasks. Measures of situational awareness, stress, cognitive performance, and workload were also obtained. In the auditory mode, position information was presented in verbal messages. In the visual mode, the same information was provided in text and graphic form on a map of the area of operation presented on a helmet-mounted display (HMD). During the study, 12 military volunteers navigated densely wooded unmarked paths that were 3 km long. Although no differences were found between the two display modes in the frequency at which navigational and other tactical information was accessed, the analysis of responses to probe questions indicated that participants maintained a greater awareness of position with respect to waypoints, targets, and other units when information was presented visually than when information was presented auditorily in verbal messages. In the auditory mode, as the participants' perceptions of time demands increased, post-test scores on a logical reasoning task tended to be higher than pre-test scores. Although visual presentation of information appeared to enhance position awareness, differences between the two display modes in navigation and target acquisition performance were not found to be statistically significant. The findings of the investigation suggest differences in cognitive processing requirements between the two displays and the impact of attentional focus and practice on cognitive performance.

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